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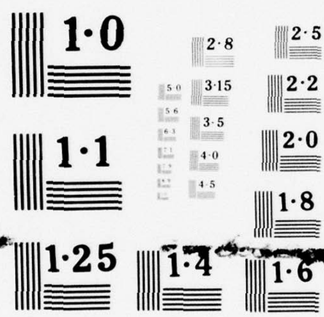

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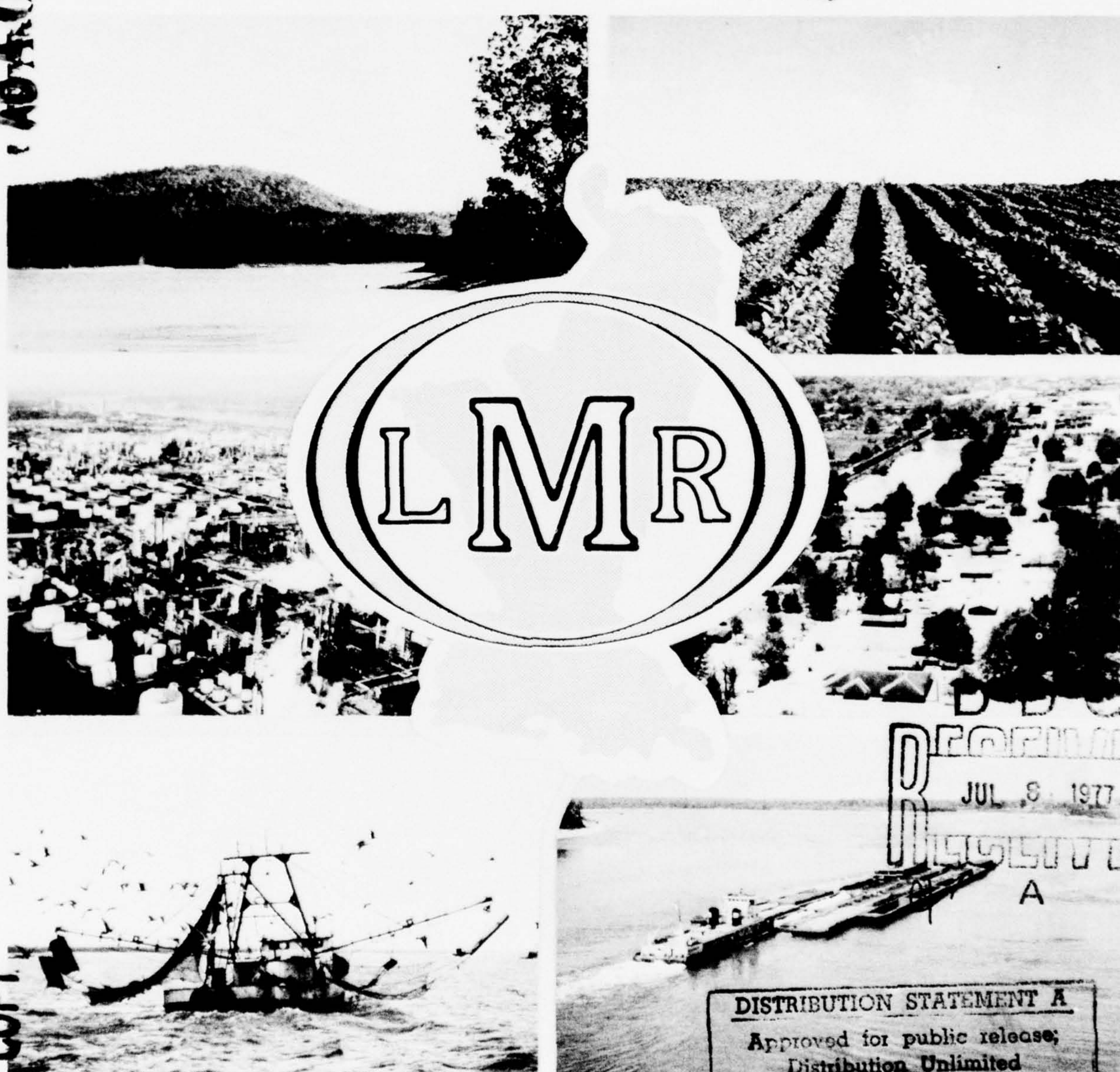
Lower Mississippi Region

Comprehensive Study



Appendix C, Volume I

Regional Climatology Hydrology & Geology

1974

This appendix is one of a series of 22 documents comprising the complete Lower Mississippi Region Comprehensive Study. A list of the documents is shown below.

Main Report

Appendixes

Appendix	Description	Appendix	Description
A	History of Study	K	M and I Water Supply
B	Economics	L	Water Quality and Pollution
C	Regional Climatology Hydrology & Geology	M	Health Aspects
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		U	The Environment

REGIONAL CLIMATOLOGY, HYDROLOGY AND GEOLOGY

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(6) (11) 1974

(12) 336p.

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LOWER MISSISSIPPI REGION COMPREHENSIVE STUDY.

Appendix C. Volume I.

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THE LOWER MISSISSIPPI REGION COMPREHENSIVE STUDY
COORDINATING COMMITTEE

410 262

This report was prepared at field level by the Lower Mississippi Region Comprehensive Study Coordinating Committee and is subject to review by interested Federal agencies at the departmental level, by Governors of the affected States, and by the Water Resources Council prior to its transmittal to the President of the United States for his review and ultimate transmittal to the Congress for its consideration.

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PHOTOGRAPHS

The photographs included in this appendix were furnished by:

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INTRODUCTION

PURPOSE AND SCOPE

The purpose of this appendix is to assemble climatologic, hydrologic, and geologic information in a summarized form for use in the planning and development of the water and related land resources of the Lower Mississippi Region. Detailed information on the present quantity, quality, availability, and use of surface water and ground water in each of the 10 Water Resources Planning Areas (WRPA) of the region is presented in this appendix. This information was obtained primarily from published sources or from computer analysis of measured parameters. Included in the regional summary or in each WRPA section are a general hydrologic and geologic description of the area; a detailed description of the climate; and a discussion of water use, stream management practices, water rights, and streamflow characteristics in the area. The total quantity of water generated in each WRPA (except WRPA 1, the Mississippi River, and WRPA's 8, 9, and 10, which are influenced by tidal action) was computed and is discussed in the surface water sections of each WRPA section. Streamflow data for selected streams were analyzed and summarized as follows: (1) observed mean discharge for the period of record available at the site; (2) annual peak discharge frequency curves; (3) low flow frequency curves; (4) duration curves of daily flows; (5) lowest mean flows for from 1 to 10 consecutive years during the period of record of streamflow at each station; and (6) seasonal and annual variations in discharge and precipitation. A general summary of ground water resources of the region is presented and discussed in this appendix. Descriptions of the geologic units that form major aquifers and the hydrologic characteristics of the aquifers are included. Potential yield data and data regarding the chemical quality of ground water in the region are presented and discussed in each WRPA section through the use of maps and tables.

DEFINITION OF "PRESENT CONDITIONS"

The discharge values presented for various streamflow gaging stations in this appendix are flows which are representative of the hydrologic conditions in the Lower Mississippi Region under 1973 levels of development. These hydrologic conditions are referred to throughout the appendix as "present conditions."

Flows representing "present conditions" at sites where streamflow has not been regulated are given for the entire period of record available at the site. At sites where the streamflow patterns have been changed due to channel improvement, reservoirs, or diversion projects,

only the flows for the period of record since completion of the projects are presented. At sites where improvement works have been recently completed, the frequency and duration curves from recorded preimprovement data were modified to reflect streamflow patterns which are expected with the projects in operation.

RELATIONSHIP TO OTHER APPENDIXES

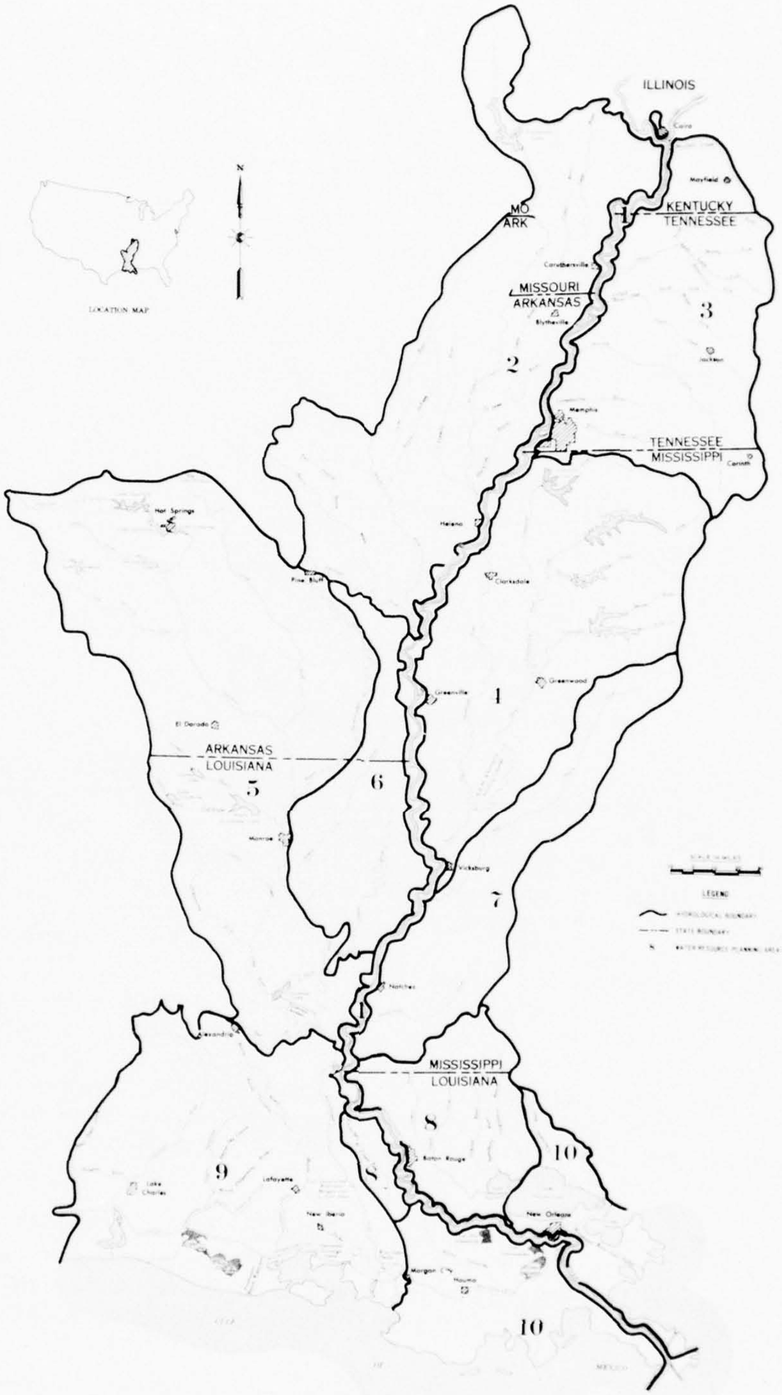
One of the major goals of the Lower Mississippi Region Comprehensive Study is to analyze the potential resources available in the region in terms of surface water, ground water, and land. This appendix provides basic information concerning the quantity and quality of both surface water and ground water for use in defining present conditions with respect to the availability of water in other supporting appendixes. This water resources information will be used in conjunction with data on future water use presented in other supporting appendixes to determine deficiencies and excesses of water for each alternative plan of water resources development in the plan formulation phase. Data from Appendix C were also used in the formulation of the present water situation in the Summary Report of the Lower Mississippi Region Comprehensive Study. Other basic data documents are the Land Resources, Mineral Resources, and Economics Appendixes.

DESCRIPTION OF THE REGION

Location and Drainage

The Lower Mississippi Region, an area of abundant natural resources, lies chiefly in the Gulf Coastal Plain and is roughly bisected by the Mississippi River. The region is composed of about 102,400 square miles of land and water, which is equivalent to about 4 percent of the conterminous United States. It extends from the confluence of the Ohio and Mississippi Rivers to the Gulf of Mexico. About 4,800 square miles, or 4.7 percent of the region, are covered with water, and the remaining 97,900 square miles are land areas.

The region includes all of the drainage area of the Lower Mississippi River below Cairo, Ill., except for that portion of the White, Arkansas, and Red River Basins which lie above the effects of backwater from the Mississippi River. It also includes the Louisiana Coastal Area between the watershed boundaries of the Pearl and Sabine Rivers, and the small flood-protected area at Cairo, Ill. The region encompasses most of Louisiana, about half of Arkansas and Mississippi, parts of Missouri, Tennessee, and Kentucky, and a small area in Illinois. Figure 1 is a map of the Lower Mississippi Region showing the regional, WRPA, and



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

REGIONAL MAP

FIGURE 1

State boundaries; the major cities; the major streams and lakes; and other pertinent data.

Drainage from about 49,740 square miles, or roughly half of the area within the Lower Mississippi Region, flows into the Mississippi River from its major tributary streams. The remainder of the region, which lies within the coastal area, is drained by southeastern Louisiana streams that flow through Lake Pontchartrain to the Gulf of Mexico and by southwestern Louisiana streams that drain directly into the Gulf.

The Mississippi River has made major contributions to the physical and economic growth of the Lower Mississippi Region. It has given the region a tremendous potential for meeting water supply and water transportation needs for industrial and agricultural development. It is of great importance to the ever-growing commerce of the Nation as the main stem of a major network of over 12,000 miles of navigable inland waterways. It is one of the Nation's greatest industrial attractions and is the chief supplier of water for the many industries which have located along its banks. It serves as the major drainage outlet for runoff from over 41 percent of the 48 contiguous states of the United States. The entire Mississippi drainage basin covers more than 1,245,000 square miles and includes all or parts of 31 States and two Canadian provinces. Water from as far east as New York and as far west as Montana contributes to flows in the lower river [122]. 1/

Major tributary streams to the Lower Mississippi River are the St. Francis River in Arkansas and Missouri, the White and Arkansas Rivers in Arkansas, and the Yazoo River in Mississippi. Other major streams in the region that are not tributaries to the Mississippi River are the Ouachita-Black River in Arkansas and Louisiana and the Red River in Louisiana. Flow from the Black and Red Rivers, combined with flow diverted from the Mississippi River through the Old River Control Structure, forms the Atchafalaya River in southern Louisiana. The Atchafalaya, Calcasieu, and Mermentau Rivers are major coastal area streams which flow into the Gulf of Mexico. Other coastal area streams such as the Amite and Tchefuncta Rivers flow to the Gulf by way of Lake Pontchartrain. The Arkansas, White, and Red Rivers contribute a considerable amount of flow into the Lower Mississippi Region from other regions, whereas the flows from all the other tributary streams mentioned above are generated within the region.

The Lower Mississippi Region includes the Mississippi Alluvial Plain, uplands in the Gulf Coastal Plain, and areas outside the coastal plain in the Ouachita Mountains in Arkansas and the Ozark Plateaus in Missouri. About one-third of the region is in the low, relatively flat

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1/ Numbers in brackets refer to reference numbers of publications listed in References.

alluvial valley of the Mississippi River. The coastal plain uplands are gently rolling to hilly, and the areas outside the coastal plain exhibit considerable variation in topography.

A distinct characteristic of the Mississippi River and other alluvial valley streams is the formation of natural levees along the banks and the pattern of parallel drainage which results from these levees. When the Mississippi River overflows, it deposits a part of the sediment it has been transporting. This sediment, most of which is deposited adjacent to the river, forms low natural levees along the stream with smaller deposits of sediment away from the stream. As a result, the banks of the river are usually 10 to 15 feet above the adjacent lowlands. The formation of these levees occurred for the most part before the present levee system was built. Because of the natural levees, drainage is usually away from and parallel to the Mississippi River except where tributary streams join the river. This pattern of drainage has been a great advantage in the construction of flood-control works, since it permits the building of long, unbroken levee lines without interfering with drainage.

General Geology

The Lower Mississippi Region has been characterized by subsidence accompanied by cyclic transgressions and regressions of the sea since the end of the Paleozoic Era about 225 million years ago. The subsidence resulted in the formation of the Mississippi embayment syncline, a structural trough now filled with sedimentary rocks (figure 56). Rocks of Precambrian age are exposed in the Lower Mississippi Region only in areas outside the embayment in Missouri. Rocks of Paleozoic age are exposed in Missouri and Arkansas.

During the subsequent Cretaceous Period, 136 million to 65 million years ago, cyclic marine invasions extended farther northward than previously as subsidence continued. During the Tertiary Period, 65 million to 2 or 3 million years ago, each marine invasion stopped successively farther to the south. The oldest units in the Gulf Coastal Plain (of Cretaceous age) crop out roughly parallel to the periphery of the Mississippi embayment. The younger units exhibit less arcuate outcrop belts and the exposures of the Miocene and Pliocene units nearly parallel the axis of the Gulf Coast Geosyncline (figures 55 and 56).

Pleistocene glaciation caused a lowering of sea level which resulted in changes in drainage and the entrenchment of the Mississippi River Valley into Tertiary and Cretaceous rocks. The enormous volumes of water from melting glaciers were discharged southward to the Gulf of Mexico, and the valley was entrenched more than 100 feet deeper than the present surface of the alluvial plain. As sea level rose, stream gradients decreased and the entrenched valley was filled with sediment.

Erosion of the Coastal Plain deposits, the partial replacement of the eroded strata by the deposits now underlying the Mississippi Alluvial Plain, and the continuing differential erosion of the upland strata have resulted in the diverse topography of the region.

Physiography

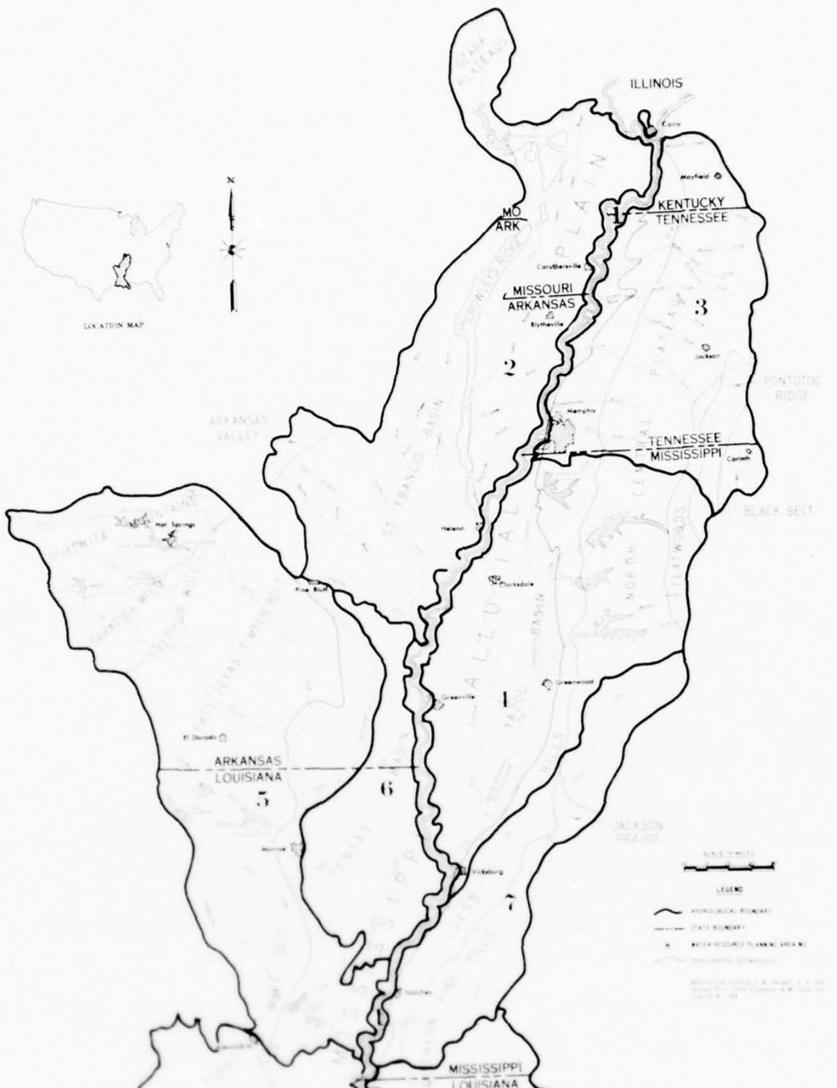
The Mississippi Alluvial Plain is the most extensive physiographic district in the region (figure 2). The plain is a flat to slightly undulating surface underlain by Pleistocene and Recent alluvial and terrace deposits. Included is the present floodplain of the Mississippi River, underlain by Holocene alluvium, and areas west of the river and above the floodplain that are underlain by Pleistocene alluvial deposits. The alluvial plain comprises the St. Francis, Tensas, and Yazoo Flood Basins [32] and the Deltaic Plain [33]. Crowley's Ridge, a narrow segmented ridge about 200 miles long, is an erosional remnant of the Gulf Coastal Plain uplands. The strata forming the ridge are similar to strata in the bluffs forming the eastern boundary of the alluvial plain. The ridge is as much as 250 feet higher than the alluvial plain. All other topographic features in the alluvial plain are developed on Quaternary deposits.

Physiographic districts in the Gulf Coastal Plain uplands are developed on Cretaceous and younger sediments. Physiographic districts in the uplands have resulted from differential erosion of unconsolidated sand, clay, and chalk strata and, in some areas, loess.

The Black Belt district is developed on the easily erodible Cretaceous chalk and clay in the northeastern part of the region. The Black Belt is a gently rolling terrain characterized by dark soil and intermittent streams. The Pontotoc Ridge, which borders the Black Belt on the west, owes its rough topography to the resistant sandstone and limestone of the Ripley and Clayton Formations. In the western part of the region, resistant Cretaceous strata, mostly sand and gravel, underlie the Saratoga Wold. The wold is a discontinuous ridge, or cuesta, that trends northeast-southwest and merges into the Ouachita Mountains at the Fall Line.

In northern Mississippi, the Flatwoods District is a low, moderately rolling terrain underlain by the Porters Creek Clay. The district narrows northward and gradually becomes indistinguishable from the North Central Plateau in southern Tennessee.

The North Central Plateau is the dominant upland physiographic district in northern Mississippi and western Tennessee. The plateau is the result of erosion of an area where blanket deposits of Quaternary sand and gravel overlie sand and clay strata of the Wilcox and Claiborne Groups. Much of the region in the past was also covered by Quaternary



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

PHYSIOGRAPHIC MAP

FIGURE 2

loess. The North Central Plateau, underlain by several belts of permeable strata, is an area of recharge for aquifers and the source area for most of the eastern tributaries of the Mississippi River in the region.

In central Mississippi, the outcrop of the Jackson Group forms the Jackson Prairie, a district characterized by gently rolling terrain developed on nearly impermeable clay. Southern Mississippi and northeastern Louisiana are in the Southern Pine Hills District, a predominantly sandy terrain underlain by geologic units of Oligocene, Miocene, Pliocene, and Quaternary age. The highest areas in the district are hills and ridges where blanket deposits generally referred to the Citronelle Formation have not been completely eroded.

Extending from Louisiana to Kentucky, the Loess Hills District borders the eastern side of the Mississippi River Alluvial Plain. The district is an area where loess deposits have not been completely removed by erosion and the terrain is characterized by steep slopes.

The uplands in the western part of the region are mostly in the East Texas Timber Belt, a district developed on the sand and clay strata of the Claiborne and Jackson Groups and, in some areas, on overlying Quaternary deposits. The district, an area of recharge for aquifers in the Claiborne Group, is bordered on the northwest by the Sulphur Wold, a ridge developed on the outcrop of the Wilcox Group.

In southern Louisiana, the Pine Flats, Pine Meadows, and Coastal Prairies and Marshes are low, gently sloping to nearly flat terrain underlain by Quaternary deposits. The Pine Flats and Pine Meadows are recharge areas for some of the most prolific artesian aquifers in the region, and the flow of streams is sustained by large quantities of ground water discharged in the areas.

The Coastal Prairie and Marsh Zone forms a gently sloping to flat belt about 50 miles wide bordering the Gulf of Mexico.

Three areas in the Lower Mississippi Region are outside the Gulf Coastal Plain. The Ozark Plateaus in Missouri form a maturely dissected rolling upland developed on gently uplifted rocks ranging in age from Precambrian to Pennsylvanian; however, in the region of study, most of the rocks are of Precambrian, Cambrian, and Ordovician age. The oldest rocks exposed in the region are the Precambrian felsitic volcanic and basic intrusive rocks that form the St. Francois Mountains. Taum Sauk Mountain (altitude 1,772 feet) in Iron County, Mo., is one of the highest points in the Lower Mississippi Region.

In southwestern Arkansas, the study includes a part of the Ouachita Mountains. The principal physiographic districts are the Athens Piedmont Plateau and the Novaculite Uplift. The entire area has been

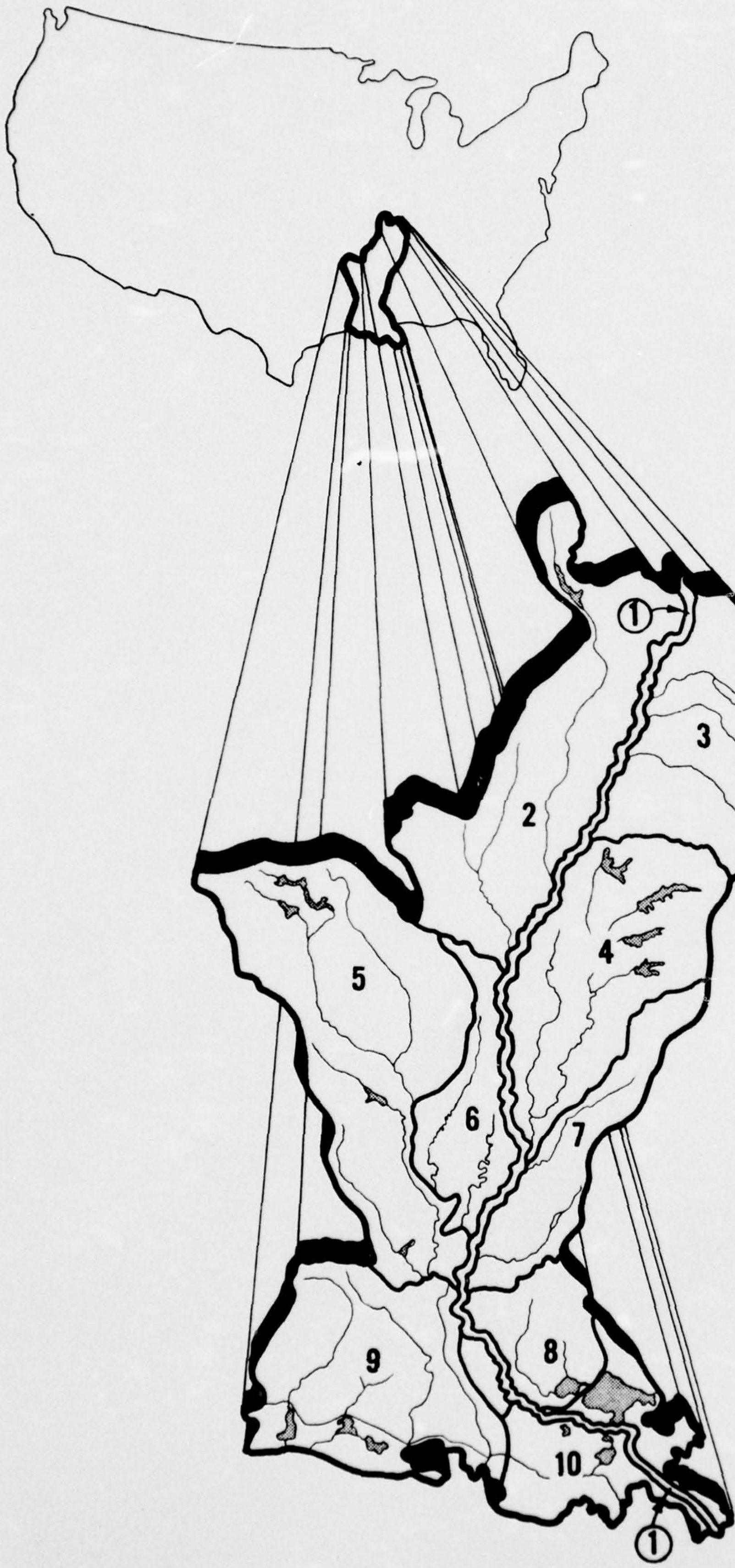
considerably disturbed by uplift, folding, and faulting. The highest point in the Lower Mississippi Region, 2,211 feet above sea level, is in the Ouachita Mountains in western Montgomery County, Ark. The Arkansas Valley, a synclinal feature lying north of and parallel to the Ouachita Mountains, is underlain by Pennsylvanian sandstone and shale.

Water Resources

The region is "water rich," but the water resources are not unlimited nor is the distribution of water uniform. The largest and most prolific aquifer, the Mississippi River Valley alluvial aquifer, is perhaps the largest single source of fresh ground water in the Nation. This shallow source of water is underlain by a complex system of artesian aquifers in Paleozoic, Cretaceous, Tertiary, and Quaternary rocks, some of which contain fresh water at depths of more than 3,000 feet. A few areas, chiefly lowlands bordering the Gulf of Mexico, are not underlain by fresh-water aquifers. Surface-water resources include the Nation's largest source of surface water, the Mississippi River, several large streams tributary to the Mississippi (St. Francis and Yazoo Rivers, for example), and several streams draining directly into the Gulf of Mexico, of which the Atchafalaya River is the largest.

Land Use

The present utilization of land reflects the agricultural economy of the region. About 86 percent of the land is used for crops or pasture or is forested. Urban and built-up areas occupy about 4 percent of the region and large water areas (over 40 acres) about 4 percent. Federal land and small water areas account for the remainder of the region.



REGIONAL SUMMARY

R E G I O N A L S U M M A R Y

CLIMATE

General Introduction

Climate is a synthesis of the weather. Weather is the total condition of the atmosphere at any instant in time; climate is the collective of all weather conditions for a given long period of time.

Weather and climate form a regional matrix within which other physical processes operate. They may be viewed as a natural resource, and are of considerable consequence to everyone, directly affecting health, living habits, and prosperity of individuals, communities, and regions. Usually a valuable asset underlying agricultural productivity and adaptation, industrial development and transportation systems, indeed all economic pursuits, weather in its extremes can produce seriously detrimental effects as well.

The broad and diverse balance of natural resources found in the Lower Mississippi Region includes abundant water resources provided by weather patterns acting both within the region and beyond. The substantial agricultural and forestry resources of the region have been developed in response to man's needs and the general regional climatic controls. Activities in the unique coastal zone, richly diverse in its biota and with significant extractive industries, commercial fisheries and extensive primary and secondary processing activities, are influenced strongly by its climate. The region's bounty of aesthetic, recreational, and wildlife resources is also closely related to the climatic pattern.

Man's primary activities during the many generations of occupancy of the region have adjusted through time to the climatic normals and extremes. Man has already learned to temper those unfavorable aspects of the natural climate--albeit on a restricted scale--through efficient heating and cooling devices for home, office, and factory; through irrigation and drainage of farmlands and developed areas; and through other ameliorative techniques.

The scientific study of weather and climate is of recent origins. Tremendous advances have been made during the past half-century in observing, describing, and understanding the extremely complex interrelations of the thermodynamic and hydrodynamic systems which produce weather. Although ever-increasing interest in these important fields has developed, significant applied problems are still unresolved. Sophisticated research continues as it must in the face of increasing demands for agricultural products, industrial development, and

recreational facilities. Further understanding will assist in future rational comprehensive planning, and some prospects are now gradually emerging that may, in the future, make possible significant beneficial weather modification programs (69, 173).

The following sections are designed to provide some limited insights into the varied aspects of the climatic patterns in the Lower Mississippi Region. This material has been prepared on local and regional bases, without specific regard to river basin or WRPA boundaries. Previously published material has been used for most of the information base, although some sections are based on previously unsummarized material. Numerous routine and special weather data publications are listed and format examples shown in the "Selective Guide to Climatic Data Sources" (144).

Climatic Character of the Region

Climatic Controls

The climate of the entire Lower Mississippi Region is classified basically as humid subtropical with abundant precipitation (116). Many interrelated factors in the general circulation of the atmosphere, acting in various spatial and temporal combinations, are of significance in producing the observed values and changes in the climatic elements found at specific places. These climatic controls include, in addition to the basic geographic and topographic setting, the locations and intensities of semipermanent features of circulation; the types and frequencies of air masses; the effects of linear weather systems (fronts, squall lines, easterly waves); and the locations, paths, and intensities of tropical and middle latitude cyclones. Also, the several climatic elements themselves can function as controls. The major climatic controls acting in the Lower Mississippi Region are discussed below.

Geography and topography. The Lower Mississippi Region is a south-central sector of eastern North America, with latitudinal extent roughly 29°N to 37°N. Bounded on the south by the Gulf of Mexico, the region is one of very minor elevational relief throughout much of its extent. This location, near the northern limits of the astronomical tropics, controls the receipt of solar radiation, which supplies energy for both the hydrologic cycle and for photosynthesis in plants.

The coastal areas of Louisiana, encompassing the delta of the Mississippi River and extensive zones of marshes and swamps, grade northward into the broad main alluvial valley bounded by upland areas of modest relief. The highest elevation in Louisiana is only 535 feet, and elevations near the Mississippi in the eastern portion of Arkansas and western Tennessee are in the 200- to 300-foot range. Although this

relatively minor relief is negligible in its direct influence on the climate, the location of the Lower Mississippi Region, positioned between major air mass source regions, and the openness of the country with no significant barriers to air mass movements combine to produce both dynamic variety and remarkable uniformity of the climate, contrasting features found in combination in few, if any, other regions of the world.

Semipermanent anticyclone. The climate of the Lower Mississippi Region is controlled to a large degree by the seasonal changes in the location and strength of the semipermanent high-pressure anticyclone of the southern North Atlantic Ocean and by connected variations in the patterns of development, movement, and intensities of cyclonic storms in subtropical and middle latitudes.

In winter, when the anticyclone is located, on average, in the far southern and eastern sections of the ocean, polar and arctic air masses which develop over northern North America periodically penetrate into the Lower Mississippi Region and beyond. The lack of terrain barriers allows surges of cold air behind middle latitude cyclones to move rapidly southward, with little modification of their bitter properties. During this portion of the year, the region experiences extreme minimum temperatures lower than those in any other comparable area of the world (115). Even in winter, however, southerly flows of warm, moist air are present a large part of the time.

With the retreat northward in spring of the preferred storm track and the expansion into the region of the Atlantic anticyclone, persistent southerly winds flowing around the western margin of the high become the dominant weather pattern by May of most years.

Warm, moist, conditionally unstable maritime tropical air moves in a convergent pattern over southern portions of the region throughout the summer season.

The air is made increasingly unstable by its passage over the warmer land surface, and local showers and thunderstorms are a common afternoon occurrence. North of the anticyclone axis, however, the basic wind flow pattern is slightly divergent. The weak axis, oriented usually almost east and west, fluctuates in location from day to day from central Louisiana and central Mississippi northward. The divergence tends to reduce both the frequency and intensity of the thundershowers since it must be overcome before convective activity proceeds.

During late summer and autumn, periods of transitory higher pressure over the continent modify the wind flow patterns over the region to easterly or northeasterly, and break the constancy of the Atlantic subtropical anticyclone control. Precipitation over the region

between late September and early November reaches the annual minimum in both frequency and amount as the air flow in the weak but extensive transitional continental high-pressure region restricts the availability of moisture.

Middle latitude storms and storm tracks. The influences of extra-tropical cyclones on the region are manifold. Sharp short-term variations in temperature during winter; the location, amounts, and intensity of cool season precipitation; patterns of cloudiness; the occurrence of thunderstorms and other severe weather; occurrence of extreme temperatures--both hot and cold--even the persistence of humid tropical conditions throughout much of the warm season can all be related to the presence of cyclonic activity and its location and intensity, or to the absence of this factor.

The region is situated near, but generally southward of, the most preferred tracks of cool season middle latitude storms which develop over the Great Plains and move northeastward across the Midwestern States into the Great Lakes-St. Lawrence River regions.

During some winter and spring seasons, cyclone development is active in Texas and the northern Gulf of Mexico. In these periods, the regional weather patterns are highly variable as the interplay of cold and warm air associated with these storms occurs over the region. At other seasons, cyclonic activity is infrequent over the region and high-pressure anticyclones are the dominant surface circulation feature. They provide extended periods of only slowly varying weather conditions. Klein (55) portrays and discusses the principal tracks and frequencies of both cyclones and anticyclones during each month.

Air streams (air masses). An air mass is an extensive section of the atmosphere in which the air is horizontally homogeneous, or possesses basically similar physical characteristics. In order for this to occur, air must remain for some time in a source region, which itself must have homogeneous surface conditions. Large land and water areas with evenly distributed insolation are good source regions. A second condition is necessary for the development of distinctive air masses: large-scale subsidence and divergence (and an absence of convergence and mixing). These conditions are best developed in the semi-permanent high-pressure areas of the atmosphere. Where development of high pressure is seasonal (continental high latitudes in winter), the source region will also be seasonal.

The primary air masses affecting the Lower Mississippi Region are (figure 3) maritime tropical (developed in the Atlantic high-pressure anticyclone); continental polar (developed in winter over the prairie provinces of Canada); and maritime polar (developed over the eastern Pacific).

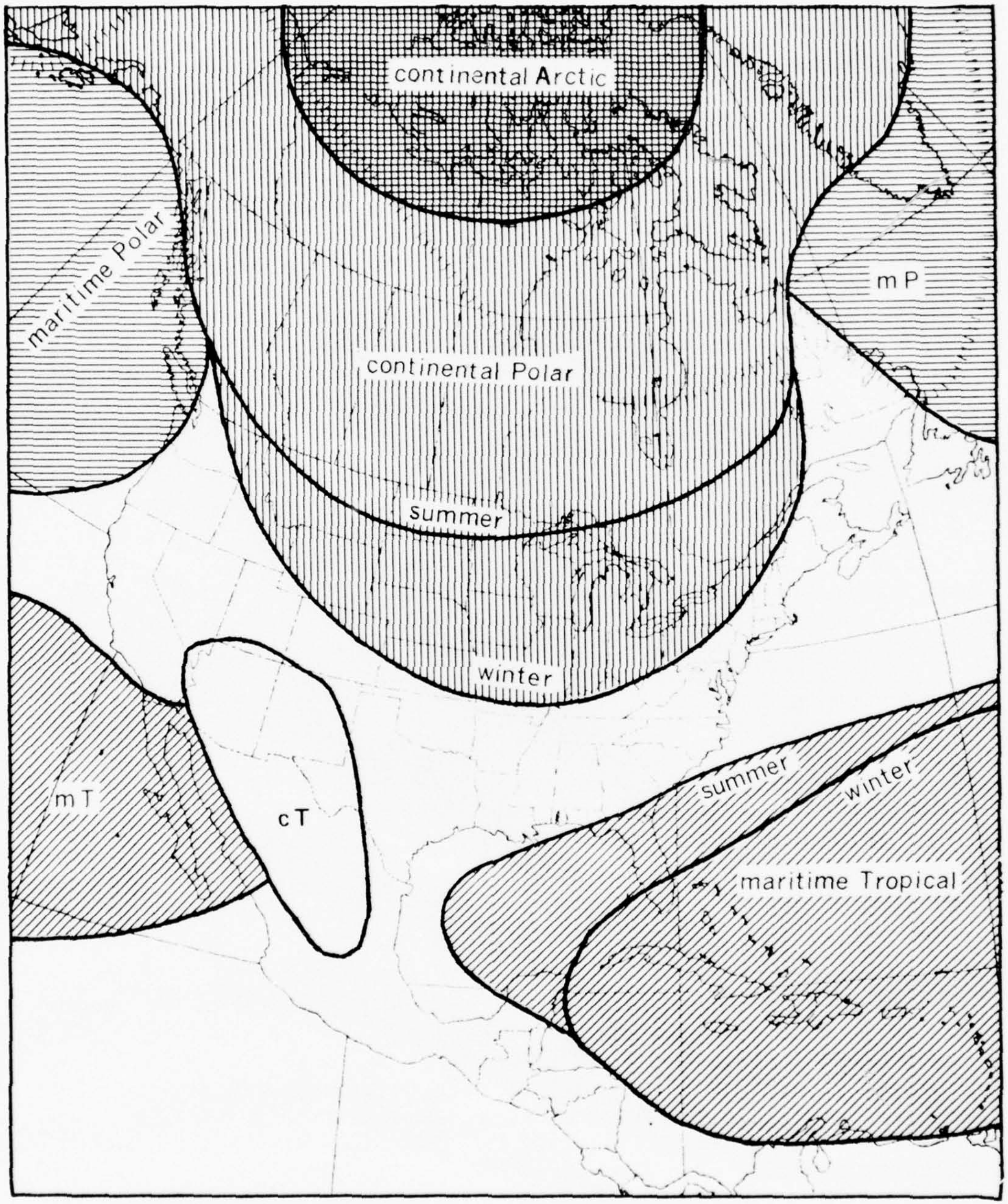


Figure 3. North American Air Masses

Linear systems. The Lower Mississippi Region is affected by three types of linear weather systems: fronts, squall lines, and easterly waves. The characteristics of these systems are described below:

Fronts are the dynamic boundaries between air masses of contrasting properties. Cold fronts (cold air replacing warm air at the surface) are zones of "weather." Enhanced convection due to the physically forced ascent of warm moist air produces abundant cumuliform clouds and in many instances short periods of heavy thunderstorm rainfall. Warm fronts (warmer air replacing cold air at the surface), in contrast, are more extensive but usually contain stratoform clouds and more extended periods of steady, lighter, nonconvective, rainfall.

Squall lines (instability lines) often develop 50 to 150 miles in advance of surface cold fronts moving across the Lower Mississippi Region. These extensive but narrow belts of heavy convection produce strong surface winds and heavy but usually brief rainfall. Unlike true fronts, they are transitory, ordinarily developing to maximum intensity in a few hours and then dissipating.

Easterly waves are perturbations in the deep summer current of tropical air flowing around the subtropical anticyclone (88). Waves of this type, moving from east to west, affect the southern sections of the Lower Mississippi Region once or twice per week during most summers. They are not present between late autumn and late spring. The easterly wave, although described by its wind field, consists of a weak trough of low pressure. Through changes in the direction of air flow, the easterly wave both enhances and depresses local convective processes. Consequently, during their passage, exceptionally clear, fine weather is followed by cloudiness and heavy precipitation, accompanied by moderate to strong winds and some squalls. This then is followed again by clearing and settled weather. The easterly wave may serve as an initial mechanism in the development of tropical cyclones.

Climatic Elements

Precipitation

Introduction. Several physical mechanisms combine in the atmosphere to produce condensation and precipitation of moisture (96). All these processes serve to cause the vertical lifting of moist air. As air rises, it expands in response to reduced atmospheric pressure and concurrently cools. The moisture capacity of air is a function of temperature, so condensation of minute water droplets or sublimation of ice crystals occurs when the air reaches saturation, and a cloud results. Precipitation does not necessarily follow immediately. For moisture to fall from clouds, the water forms must grow to sizes which cannot be supported by the buoyancy of the air. In ways not yet fully

understood, coalescence of cloud droplets through collision, sublimation, or electrical attraction produces droplets which are too massive to remain aloft. Thus, precipitation is defined (52) as any or all of the forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground.

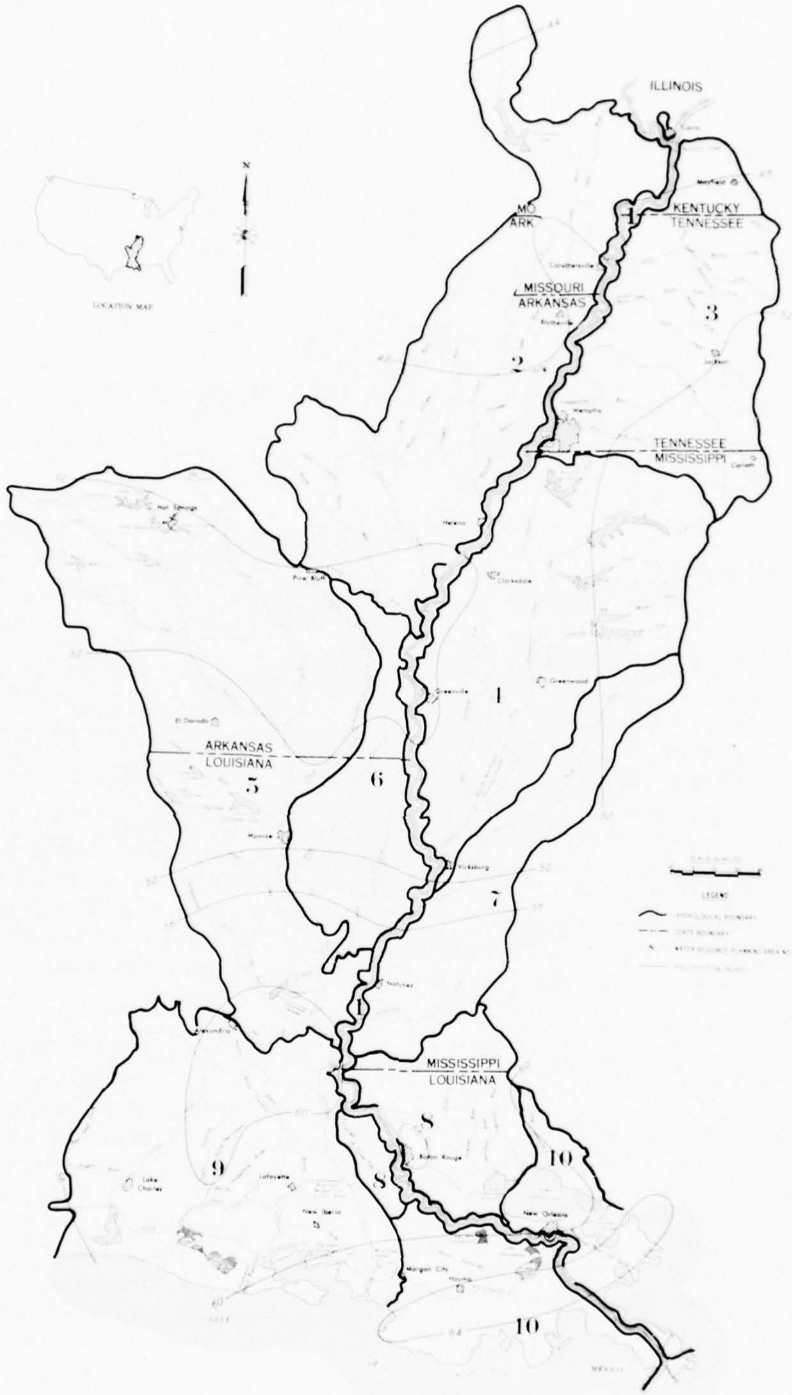
The main features of the patterns of precipitation in the Lower Mississippi Region include the following:

(1) Annual normal precipitation exceeds surface water losses through evaporation and evapotranspiration.
(2) Seasonal variations in average total precipitation display marked contrasts from north to south over the region.
(3) Precipitation is highly variable, both temporally and spatially, in the same time period.

Annual, seasonal, monthly. Precipitation is usually abundant and well distributed throughout the Lower Mississippi Region. Generalized patterns of normal annual precipitation are shown in figure 4, adapted from Climatic Atlas of the United States (141). The areas of highest precipitation are along the southeastern coastal sections of Louisiana and over much of central Louisiana (both more than 60 inches), and in the higher elevations of the Ouachita Mountains in west central Arkansas (more than 56 inches). Minimum annual precipitation (less than 50 inches) is found in the extreme northern portions of the region.

On a seasonal basis, northern sections of the region have precipitation maxima during winter (or spring) and the southern portions during summer. Trewartha (115) considers the winter maximum an outstanding anomaly in the climatic pattern. In comparable latitudinal and geographic settings on the other continents, no cool season precipitation maximum is experienced, and in those areas, the summer maximum is usually quite strong.

During winter and spring, intrusions of polar air into the region are usually accompanied by widespread and persistent cloudiness and general rainfall, plus some thunderstorm activity within the frontal zone. On the other hand, the land surface is cooler than moist tropical air moving into the region, so this air is cooled in its layers near the surface, and its stability is increased. Only when the tropical air becomes involved in convergence in cyclonic storms or is forced aloft along frontal systems does significant precipitation occur. These storms and fronts most frequently move across the northern portions of the region, so during the cooler months rainfall is more frequent and intense there.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL ANNUAL
TOTAL PRECIPITATION, INCHES
1931-1960

FIGURE 4

Autumn brings the least precipitation to the entire region as the atmospheric flow patterns move through a transitional period during which the availability of atmospheric moisture and the occurrence of precipitation-inducing mechanisms are both at annual minima.

Figures 5 through 8 (141) show the average patterns of normal (1931-1960) monthly precipitation for January, April, July, and October, respectively. These midseason months show the characteristics of the seasonal variations referred to above.

Figure 9 (149) shows monthly hyetographs for selected stations. The seasonal variations discussed above--winter rainfall maxima in northern portions, summer maxima in southern areas, dry autumns throughout the region--are further delineated here.

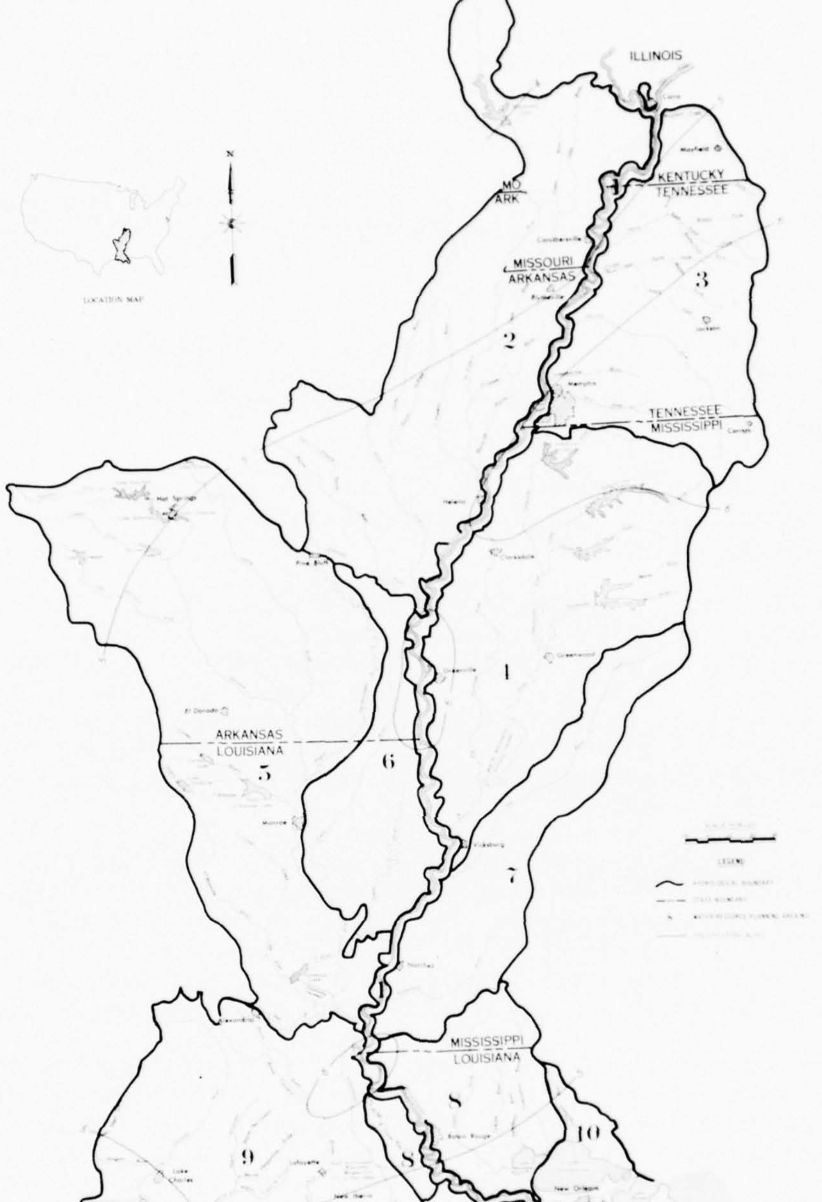
Table 1 shows the monthly and annual normal precipitation for selected sites in each WRPA, further illustrating the variations in seasonal precipitation.

The data used in figures 5 through 8 and table 1 are for the 30-year climatological standard normal period 1931 through 1960. All areas of the region usually receive measurable precipitation amounts during each month. Quite rarely, however, during the standard period covered, no rain has occurred during a few summer and autumn periods exceeding one month in duration at most places in the region. The most recent month with widespread occurrence of no measurable precipitation was October 1963 (146).

Days with various precipitation thresholds. Figure 10 (141) shows the average number of days per year with measurable precipitation in the Lower Mississippi Region. Remarkable uniformity is the basic feature of the annual pattern. The range of rainy days is only from nearly 100 along the western boundary of the region to less than 120 over southeastern Louisiana and the extreme northern portion of the region.

Figure 10 also shows the average number of "rainy days" for each midseason month (January, April, July, October). The principal features of these patterns are: (a) uniformity in January; (b) maximum rainy days in the northern sections of the region and a minimum number in southern Louisiana in April; (c) a strong maximum in southeastern Louisiana in July; and (d) a minimum centered over the central portions of the region in October.

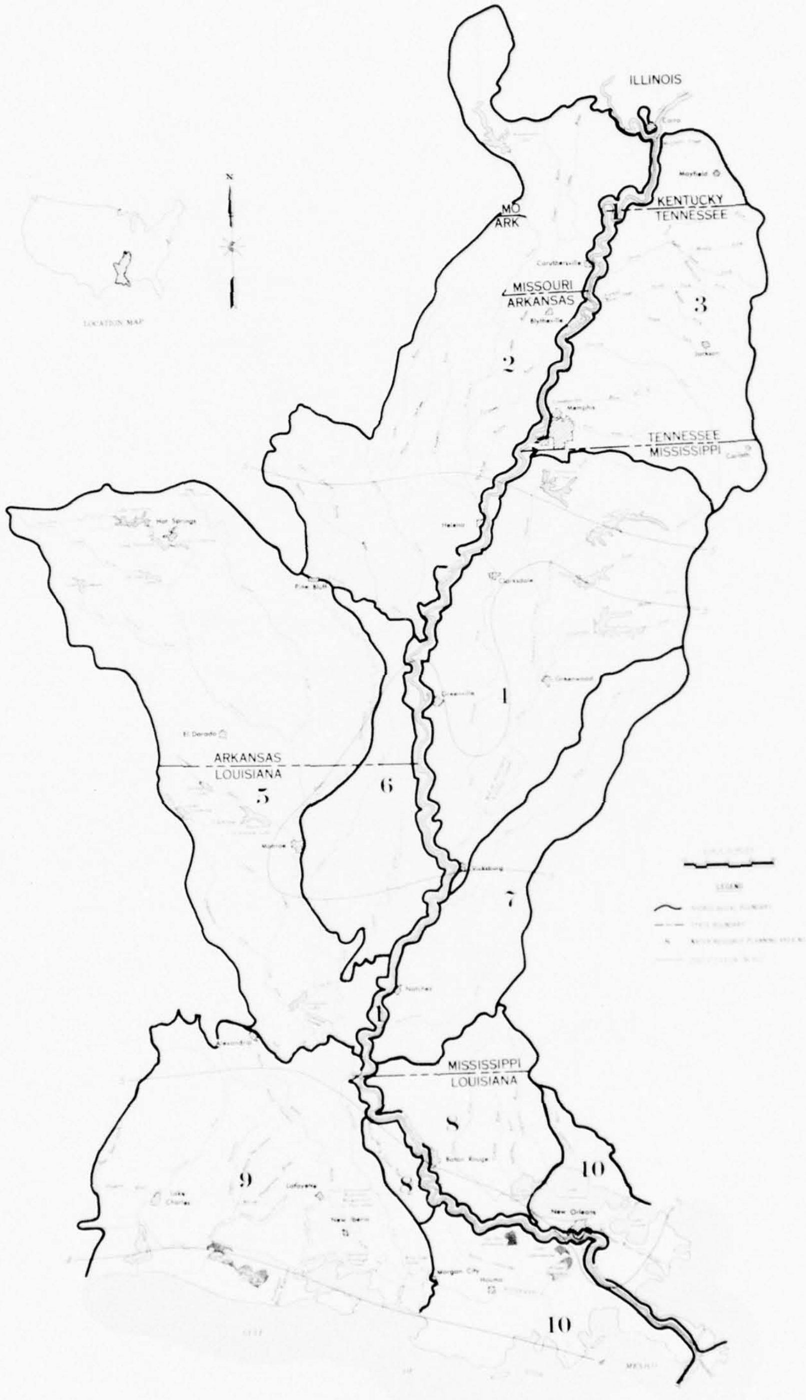
Figures 11 through 14, from Miller and Frederick (63), again for the midseason months, depict the average number of days with precipitation equal to or greater than 0.50 inch. For January, the occurrences of rains of this intensity are a maximum over the central portions of the region. In April, heavy rains are less frequent but maxima are still in the central portions. In July, a strong gradient exists in the



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL JANUARY
TOTAL PRECIPITATION, INCHES
1931–1960

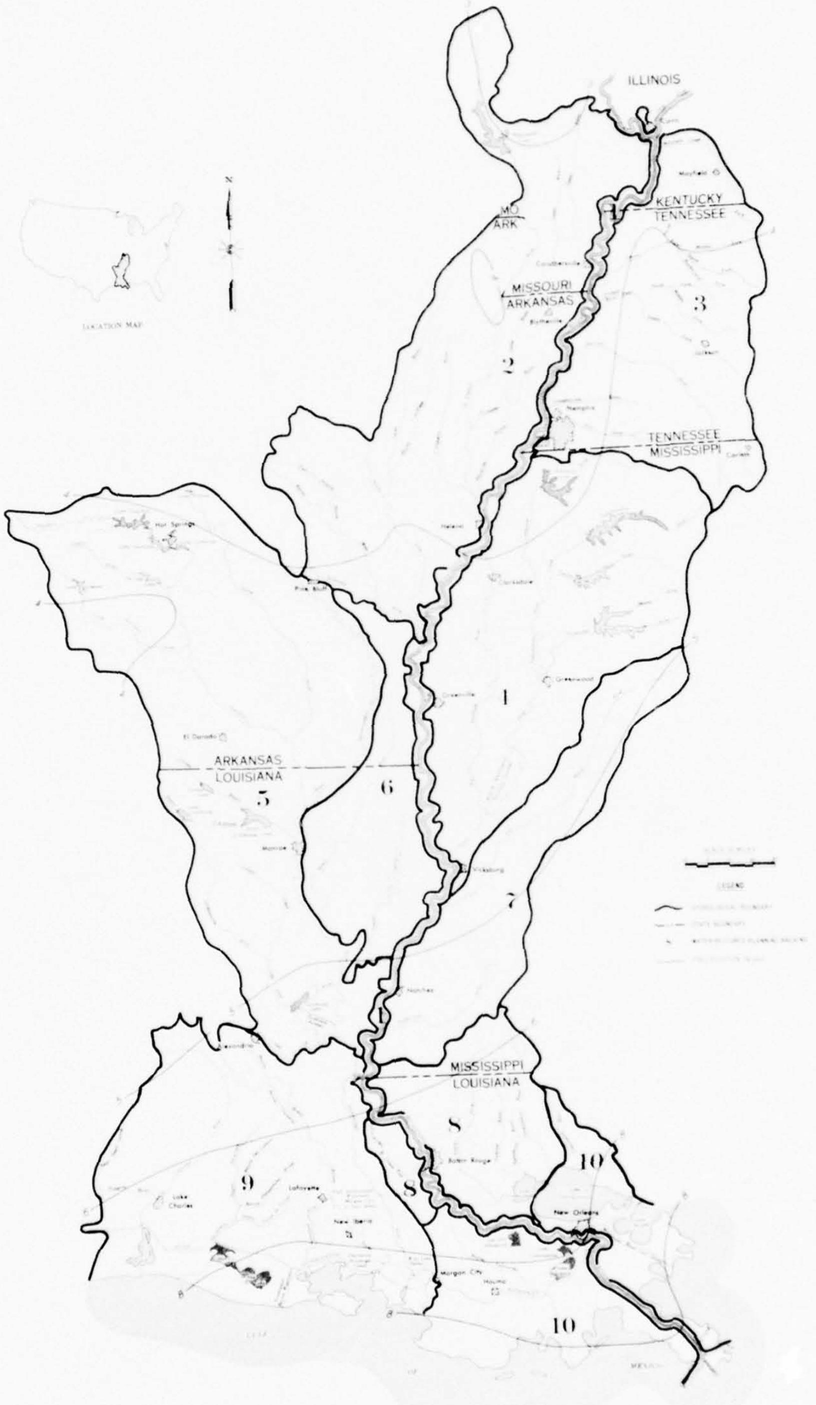
FIGURE 5



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL APRIL
TOTAL PRECIPITATION, INCHES
1931–1960

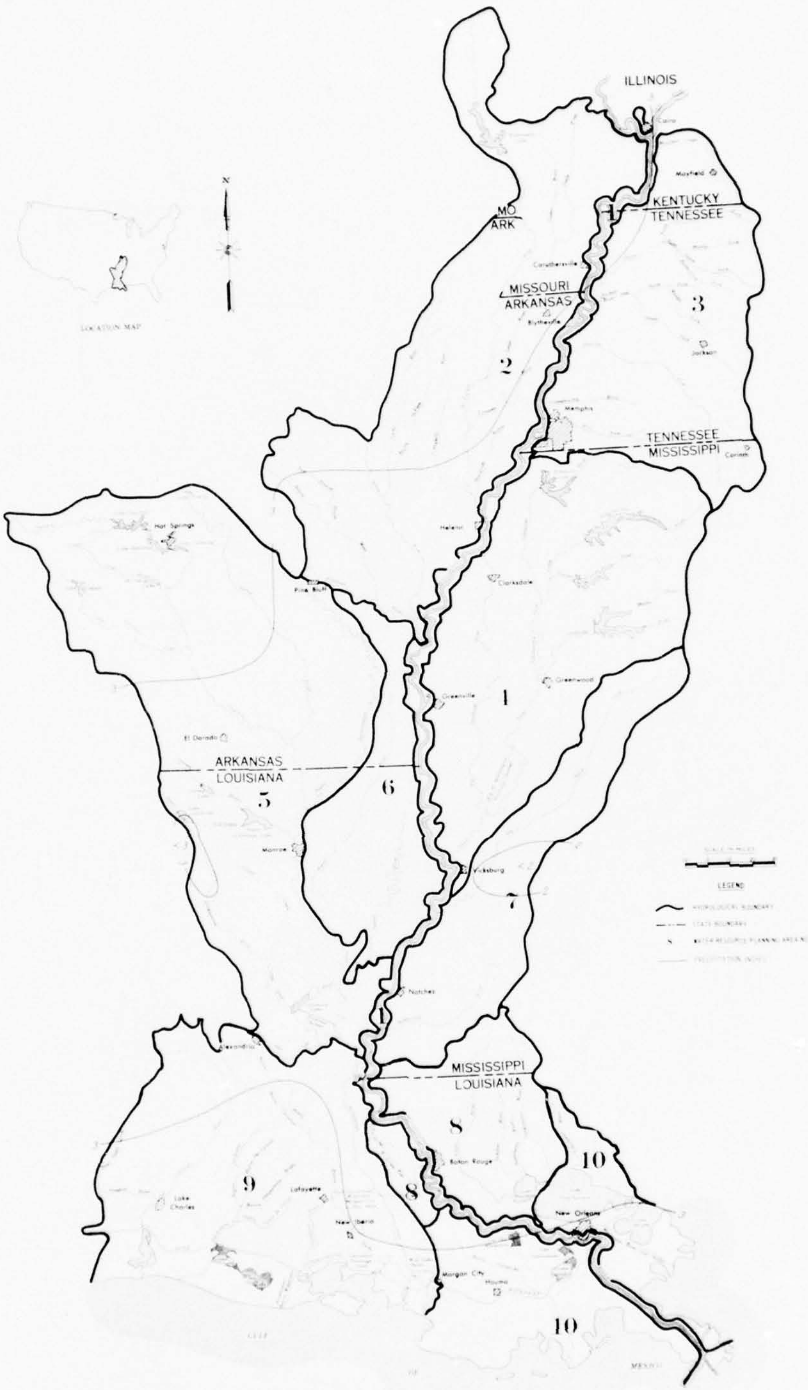
FIGURE 6



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL JULY
TOTAL PRECIPITATION, INCHES
1931-1960

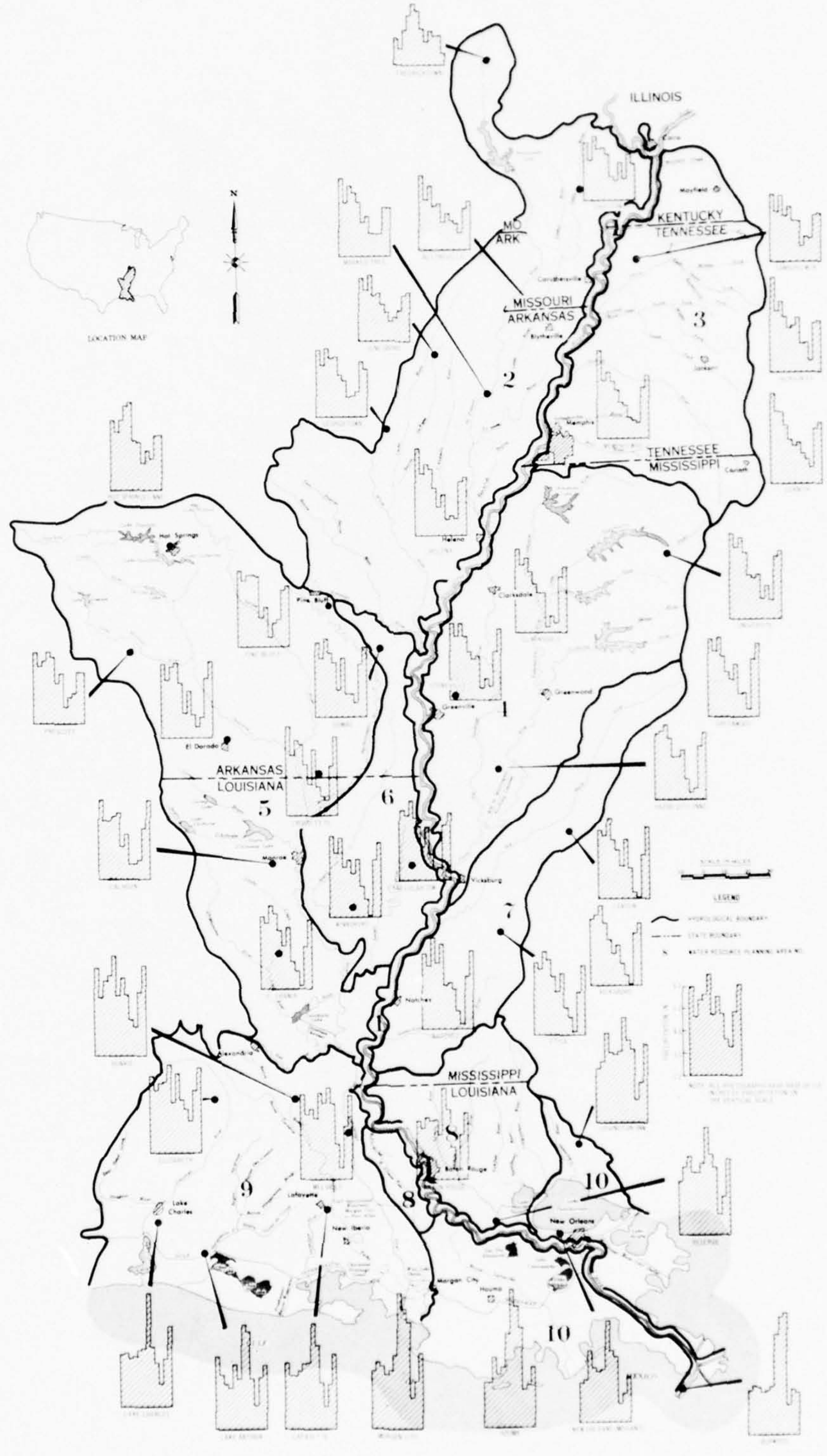
FIGURE 7



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL OCTOBER
TOTAL PRECIPITATION, INCHES
1931–1960

FIGURE 8



HYETOGRAPHS OF MONTHLY NORMAL PRECIPITATION IN INCHES FOR SELECTED STATIONS

1931–1960

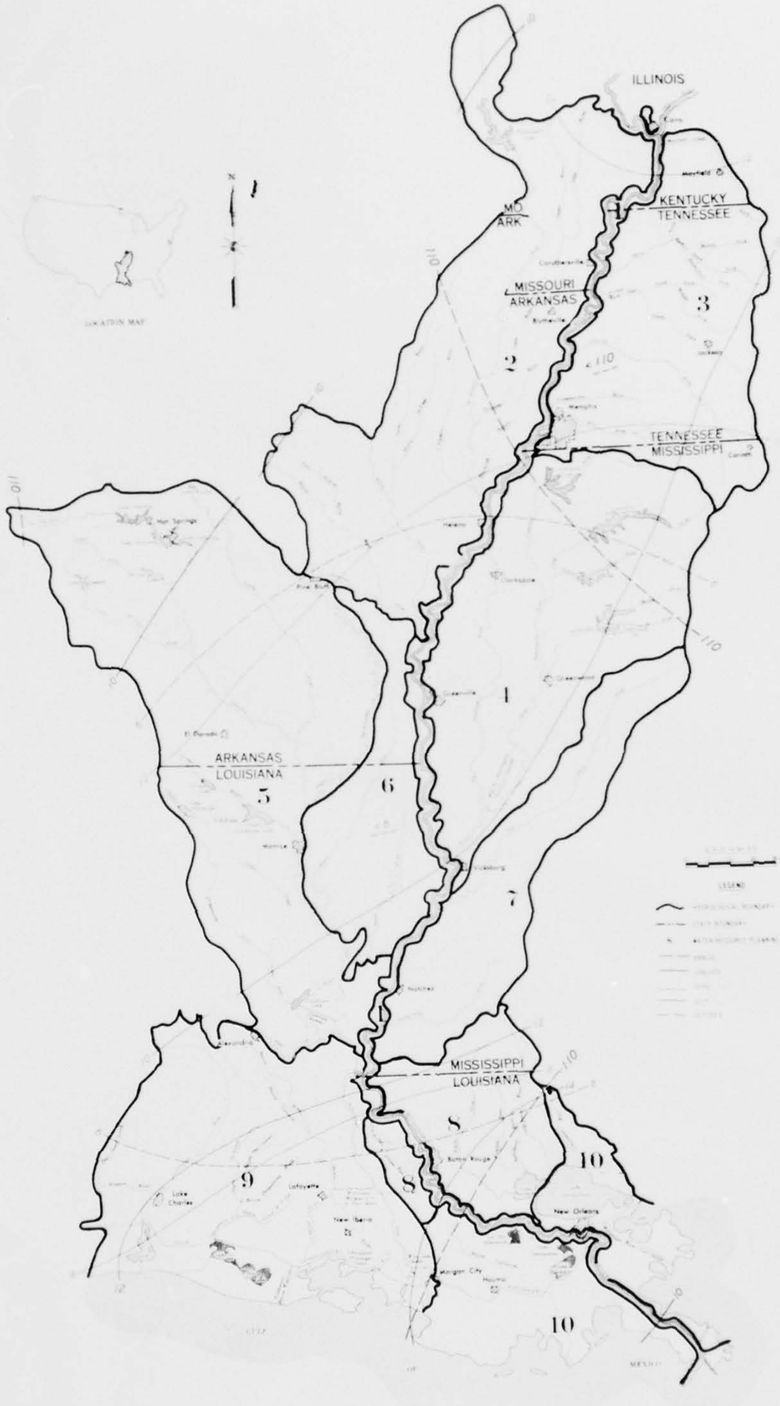
FIGURE 9

Table 1 - Monthly and Annual Normal Precipitation in Inches at Selected Stations, 1931-1960

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
WRPA 2													
Arcadia, Mo.	2.94	2.60	3.81	4.43	5.04	4.82	3.56	3.20	3.32	3.44	3.82	2.62	43.60
Dexter, Mo.	4.47	3.84	4.83	4.34	4.59	4.35	3.22	3.44	3.74	3.25	3.87	3.62	47.56
Fredericktown, Mo.	3.23	2.78	3.64	4.33	4.86	4.53	3.71	3.07	3.60	3.36	3.39	2.58	43.08
Greenville 4 NNW, Mo.	3.60	2.93	4.11	4.26	5.00	4.41	3.46	3.53	3.37	3.36	3.78	3.05	44.86
Marble Hill, Mo.	3.78	2.96	4.10	4.51	5.06	4.54	3.17	3.91	3.38	3.36	3.48	3.11	45.36
Morehouse, Mo.	4.48	3.55	4.73	4.28	4.42	4.19	2.86	3.13	3.43	3.15	4.06	3.62	45.90
New Madrid, Mo.	4.56	4.24	5.05	4.14	4.90	3.99	3.79	3.09	3.42	3.07	4.28	3.93	48.46
Parma, Mo.	4.65	3.98	4.85	4.07	4.70	4.06	3.45	3.50	3.36	2.78	4.16	3.67	47.03
Sikeston SE Mo. Research	4.67	3.86	4.99	4.40	4.44	4.16	3.12	2.92	3.79	3.00	4.18	3.71	47.24
Williamsville, Mo.	3.93	3.32	4.09	4.54	4.72	4.37	3.35	3.93	3.30	3.65	3.85	3.30	46.35
Blytheville, Ark.	5.45	4.33	5.00	4.01	4.17	3.29	3.66	3.38	3.21	2.80	3.93	4.24	47.47
Corning, Ark.	4.37	4.03	4.52	4.27	5.03	3.91	4.06	2.95	2.93	3.43	3.95	3.60	47.05
Georgetown, Ark.	5.10	4.40	5.19	4.71	4.79	3.93	3.65	2.88	2.95	3.16	4.56	4.20	49.52
Helena, Ark.	6.05	4.87	5.35	5.10	4.22	3.35	3.94	2.79	2.95	2.80	4.53	4.73	50.68
Jonesboro, Ark.	4.95	4.39	5.09	4.12	4.22	3.70	3.55	2.93	3.10	3.43	4.13	4.27	47.88
Marianna 2 S, Ark.	5.65	4.66	4.90	4.63	4.24	3.11	3.67	2.84	2.89	3.18	4.05	4.61	48.43
Marked Tree, Ark.	5.63	4.48	5.28	4.96	4.51	3.59	3.87	3.06	3.03	3.02	4.26	4.25	49.94
Newport, Ark.	4.92	4.27	4.90	4.69	5.04	4.09	3.71	3.36	2.87	3.44	4.33	4.11	49.73
St. Francis, Ark.	4.85	4.22	4.99	4.26	4.37	3.90	3.76	3.17	3.37	3.05	4.24	3.91	48.09
Searcy, Ark.	5.21	4.57	5.27	4.80	5.33	3.99	3.69	3.55	2.87	3.53	4.43	4.60	51.84
Stutgart, Ark.	5.86	4.93	5.56	5.02	4.84	3.91	4.16	3.05	3.23	2.99	4.43	4.73	52.71
Little Rock WSO, Ark.	5.22	4.33	4.81	4.93	5.28	3.61	3.34	2.82	3.23	2.88	4.12	4.09	48.66
WRPA 3													
Lovelaceville, Ky.	4.92	4.13	5.14	4.36	4.26	3.74	3.32	3.25	3.08	3.13	4.00	4.01	47.34
Bolivar 2, Tenn.	6.57	5.10	5.36	4.65	3.63	3.98	4.29	3.50	3.92	2.75	4.53	4.70	52.98
Brownsville, Tenn.	6.52	4.89	5.43	4.67	4.19	3.91	4.18	2.88	3.55	2.63	4.52	4.62	51.99
Covington, Tenn.	6.21	4.72	5.56	4.66	4.56	3.83	3.76	2.96	3.25	2.99	4.52	4.58	51.60
Dresden, Tenn.	5.76	4.46	5.29	4.36	4.40	4.01	3.87	2.84	3.12	2.83	4.22	4.47	49.63
Jackson ES, Tenn.	6.42	4.82	5.26	4.60	4.03	4.18	4.56	3.36	3.40	2.56	4.28	4.39	51.86
Memphis WSO, Tenn.	6.07	4.69	5.07	4.63	4.23	3.68	3.54	2.97	2.82	2.72	4.38	4.93	49.73
Milan, Tenn.	6.38	4.65	5.81	4.65	4.29	4.22	4.45	3.51	3.48	2.96	4.37	4.60	53.37
Moscow, Tenn.	6.01	5.36	5.45	4.56	4.11	4.30	3.85	3.44	3.39	2.71	4.38	5.08	52.64
Newbern, Tenn.	5.40	4.41	5.24	4.13	4.13	4.03	3.95	2.95	3.15	2.93	4.13	4.33	48.78
Samberg WLR, Tenn.	5.14	4.34	5.06	4.17	4.59	3.93	3.90	2.72	3.17	3.08	4.17	4.26	48.53
Selmer, Tenn.	6.30	5.42	5.34	4.59	3.81	4.31	3.88	3.22	3.37	2.88	4.29	4.80	52.21
Union City, Tenn.	5.13	4.29	5.18	4.46	4.41	3.95	4.00	2.86	3.39	3.05	4.30	4.34	49.36
Corinth, Miss.	6.23	5.38	5.35	4.72	4.02	3.77	3.95	3.40	3.16	2.77	4.56	4.84	52.15
WRPA 4													
Batesville, Miss.	6.05	4.92	5.85	5.21	3.97	3.57	4.05	3.32	3.14	2.65	4.57	5.30	52.60
Belzoni, Miss.	5.55	5.12	5.53	5.09	3.66	3.77	3.78	2.75	2.61	2.53	4.69	5.31	50.39
Clarksdale, Miss.	5.89	5.17	5.47	4.82	4.24	3.84	3.83	2.25	2.78	2.44	4.58	5.05	50.36
Cleveland, Miss.	5.88	4.93	6.34	5.05	4.28	3.97	4.65	2.53	3.32	2.82	4.64	5.22	53.63
Greenville, Miss.	6.43	5.22	5.70	5.41	4.03	3.24	4.42	2.62	3.21	2.38	4.64	5.25	52.55
Greenwood FAA, Miss.	5.62	5.04	5.70	4.81	4.06	3.75	4.45	3.06	3.12	2.39	4.70	5.41	52.11
Grenada, Miss.	5.63	5.14	6.47	4.43	4.00	3.61	4.21	3.23	3.13	2.40	4.89	5.16	52.30
Holly Springs 2 NE, Miss.	6.43	5.48	5.71	4.79	4.26	3.72	4.60	3.19	3.79	2.91	4.68	5.03	54.59
Moorhead, Miss.	5.48	4.77	5.76	5.16	3.59	3.81	4.58	2.81	3.10	2.44	4.53	4.85	50.88
Pontotoc, Miss.	5.66	5.17	6.23	5.06	3.70	4.05	4.87	3.28	3.43	2.45	4.57	5.16	53.63
Scott, Miss.	5.98	4.94	5.92	4.97	4.29	3.41	3.78	2.55	2.83	2.51	4.60	4.97	50.75
Stoneville ES, Miss.	5.59	4.98	5.56	4.96	4.21	3.87	4.03	2.55	2.99	2.61	4.23	5.28	50.86
Swan Lake, Miss.	5.77	4.91	5.89	4.83	3.87	4.03	4.54	2.75	3.03	2.46	4.73	5.03	51.84
University, Miss.	5.97	5.29	5.76	5.05	4.02	3.88	4.04	2.91	3.53	2.83	4.84	5.09	53.21
Vicksburg WSO, Miss.	5.13	5.31	5.73	4.92	4.13	3.46	3.90	3.01	2.50	2.04	4.43	4.94	49.50
Water Valley, Miss.	5.64	5.14	6.23	5.20	3.92	3.86	4.57	3.09	3.57	2.69	4.60	5.25	53.76
Yazoo City 5 NNE, Miss.	5.06	5.19	5.49	4.83	3.97	3.99	4.29	2.98	2.36	2.51	4.47	5.10	50.24

Table 1 - Monthly and Annual Normal Precipitation in Inches at Selected Stations, 1931-1960 (Con.)

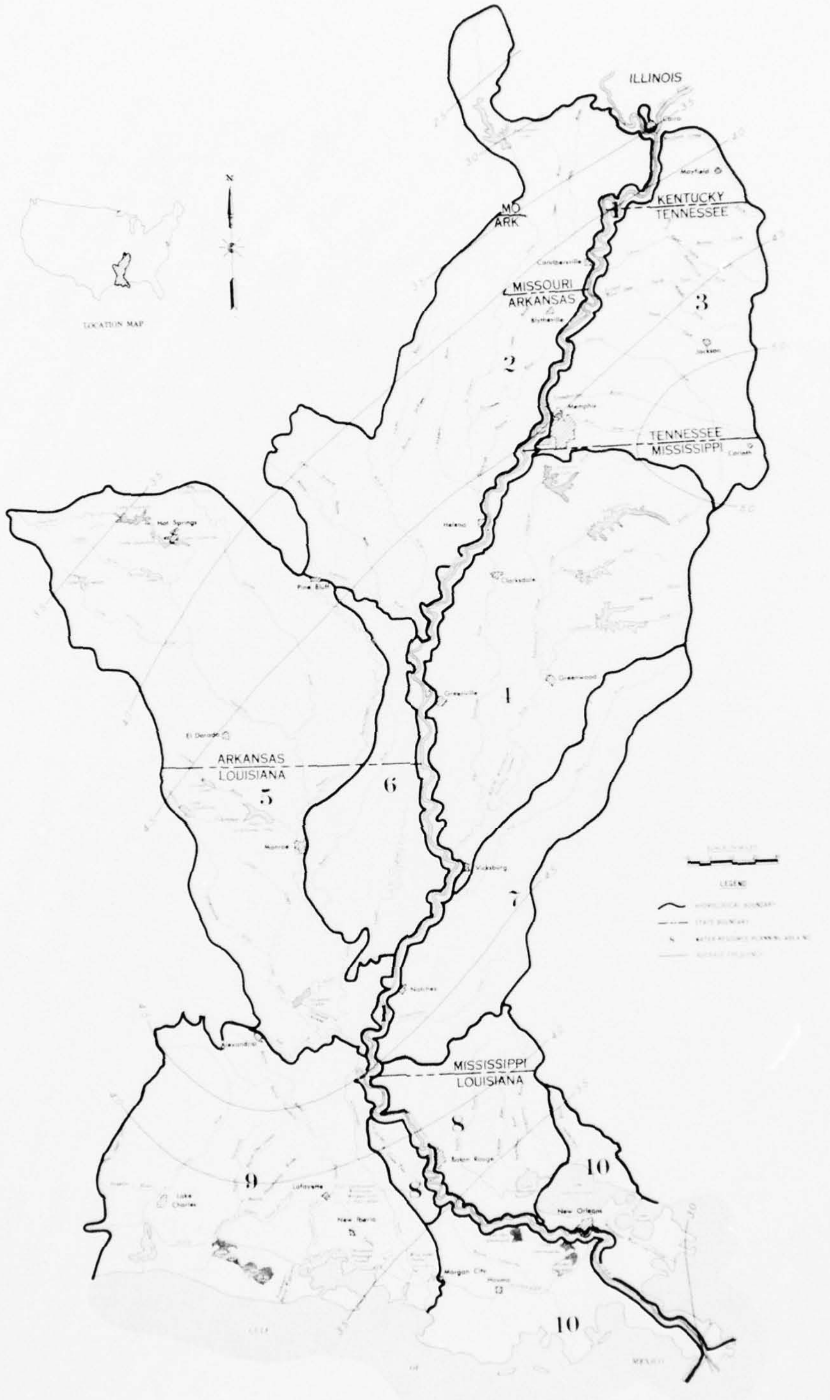
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
WRPA 5													
Arkadelphia, Ark.	5.27	4.36	5.13	5.68	5.24	3.96	3.85	2.81	3.36	3.44	4.52	4.58	52.20
Camden 1, Ark.	4.93	4.58	5.19	5.10	4.46	3.36	4.36	2.73	3.12	3.09	5.13	5.14	51.19
Crossett 7 S, Ark.	6.15	4.82	5.50	5.31	4.38	3.43	5.08	3.37	2.89	2.71	4.29	5.65	53.58
Eldorado FAA, Ark.	5.43	4.68	5.30	5.47	4.55	3.13	4.18	3.05	2.49	2.95	4.76	5.55	51.54
Fulton, Ark.	5.18	4.28	4.89	5.01	5.14	4.01	3.61	3.06	2.90	3.22	4.31	4.48	50.09
Hope 3 NE, Ark.	5.21	4.46	5.01	5.60	5.16	3.76	4.09	3.26	2.93	3.17	4.57	4.46	51.68
Hot Springs 1 NNE, Ark.	5.25	4.74	5.24	5.94	6.10	4.31	4.21	3.24	3.83	3.46	4.57	4.59	55.48
Mount Ida, Ark.	4.67	4.33	5.18	5.44	6.13	3.75	4.44	3.46	3.82	3.62	4.45	4.61	53.90
Pine Bluff, Ark.	5.58	5.10	5.33	5.36	5.28	3.38	3.84	2.42	3.10	3.28	4.63	4.83	52.13
Pine Ridge, Ark.	4.53	4.40	4.93	5.46	6.22	4.13	4.36	3.51	3.74	3.54	4.09	4.12	53.03
Portland, Ark.	5.75	4.95	5.50	4.99	3.92	3.39	4.02	2.69	2.89	2.83	4.41	4.93	50.27
Prescott, Ark.	5.34	4.64	4.92	5.36	5.09	3.89	4.36	2.79	3.22	3.42	4.41	4.39	51.83
Calhoun ES, La.	5.72	4.75	4.72	4.94	5.12	3.54	4.08	2.69	2.71	2.88	4.38	5.66	51.19
Urania, La.	6.12	5.55	6.18	5.99	5.92	3.79	5.52	3.50	2.83	2.73	4.59	5.94	58.66
WRPA 6													
Arkansas City, Ark.	6.18	4.99	6.21	5.15	4.48	3.43	4.73	2.77	3.22	2.82	4.45	5.17	53.60
Dumas 1 ESE, Ark.	5.47	4.75	6.66	5.00	4.55	3.26	4.79	3.08	3.08	2.68	4.44	5.26	52.02
Saint Joseph ES, La.	5.37	5.41	5.98	5.16	5.02	3.79	4.70	3.30	2.40	2.20	4.38	5.37	53.08
Tallulah, La.	5.27	5.01	5.72	4.89	4.52	3.55	4.46	3.20	2.49	2.59	4.58	5.14	51.42
Winnsboro, La.	5.79	5.00	5.68	4.34	4.66	4.01	4.68	3.42	2.82	2.06	4.66	5.47	52.59
WRPA 7													
Canton, Miss.	5.21	4.95	5.75	4.73	4.26	3.52	4.78	3.40	2.29	2.03	4.02	5.37	50.31
Eupora, Miss.	5.72	5.10	5.88	4.44	3.67	4.06	4.96	3.35	2.77	2.53	3.96	4.98	51.42
Jackson WSO, Miss.	4.94	4.88	5.57	4.51	4.16	3.85	4.64	3.34	2.48	1.94	3.79	5.32	49.33
Kosciusko, Miss.	5.54	5.52	5.82	4.96	4.08	3.72	5.36	3.21	2.98	2.43	4.33	5.12	53.07
Natchez, Miss.	5.52	4.94	6.24	5.08	5.98	4.03	4.18	3.86	2.83	2.21	4.46	5.64	54.97
Port Gibson, Miss.	5.60	5.47	6.09	5.67	4.95	4.44	4.88	3.87	2.86	2.41	4.47	5.41	56.12
Utica, Miss.	5.39	5.05	5.90	5.50	4.71	4.00	4.85	3.24	2.81	2.16	3.98	5.21	52.80
WRPA 8													
Baton Rouge, La.	4.78	4.42	4.91	4.77	4.80	4.09	6.27	5.26	3.52	2.45	4.09	5.10	54.46
Cinclare, La.	5.52	4.85	5.04	5.17	5.31	4.26	6.99	5.15	4.41	2.61	4.22	5.28	58.81
Donaldsonville, La.	4.76	5.09	5.05	5.14	5.66	4.62	6.22	5.74	5.40	2.73	4.33	5.13	59.87
WRPA 9													
Bunkie, La.	6.09	4.73	5.52	5.78	6.67	4.81	5.64	4.83	3.67	3.35	4.97	6.21	62.27
Crowley ES, La.	5.42	4.49	4.15	4.48	5.12	5.08	6.25	6.11	4.00	2.80	4.22	5.71	57.83
Elizabeth 1 NW, La.	5.60	4.94	5.24	5.32	6.15	4.39	5.72	4.48	4.02	3.47	4.92	5.99	60.24
Jeanerette EF, La.	4.51	4.34	4.58	4.15	4.82	5.57	8.13	6.24	4.53	2.85	3.90	5.10	58.72
Jennings, La.	5.69	4.87	4.49	4.87	5.87	5.24	6.51	5.77	4.71	3.07	4.16	6.65	60.90
Lafayette, La.	5.08	4.51	4.47	4.69	5.04	5.08	6.93	5.88	4.17	3.04	4.07	5.51	58.47
Lake Arthur 10 SW, La.	5.39	4.56	4.11	3.97	5.02	4.36	6.86	6.57	4.38	3.11	4.43	4.97	57.73
Lake Charles WSO, La.	4.44	4.51	4.24	4.37	4.61	4.72	7.29	4.80	4.02	3.06	4.22	5.76	56.04
Melville, La.	5.96	5.04	5.31	4.85	6.03	4.57	5.28	4.54	3.64	2.55	4.47	5.90	58.14
Simmesport, La.	6.01	5.02	5.75	5.53	7.01	4.76	5.42	4.42	3.20	2.99	4.97	6.40	61.48
Ville Platte 2 SW, La.	5.31	4.95	4.88	4.67	5.21	4.87	5.88	4.63	3.79	3.30	4.37	6.29	58.15
WRPA 10													
Burrwood WSO, La.	4.08	4.31	4.22	4.01	4.08	4.25	6.69	7.52	7.67	3.40	4.15	3.97	58.35
Covington 4 NNW, La.	4.54	4.84	6.18	5.26	5.19	5.31	6.89	5.82	5.41	3.04	3.85	6.64	61.97
Houma 1 SW, La.	4.11	4.09	5.27	4.48	4.81	6.39	8.43	7.62	6.63	3.76	3.99	4.81	64.39
Morgan City, La.	4.72	5.12	4.91	4.54	4.76	5.41	8.32	7.57	6.76	3.42	4.22	5.50	65.25
New Orleans WS City, La.	4.42	4.69	6.22	5.41	5.11	5.49	7.92	6.34	5.99	3.22	3.74	4.70	63.25
New Orleans WS Moisant, La.	3.84	3.99	5.34	4.55	4.38	4.43	6.72	5.34	5.03	2.84	3.34	4.10	53.90
New Orleans WS Audubon, La.	4.29	4.35	5.91	5.54	4.86	5.59	8.02	6.64	6.41	3.15	3.51	4.59	62.96
Paradis, La.	4.84	5.23	6.21	5.07	5.36	6.01	7.44	6.50	5.96	3.35	4.07	5.54	65.58
Pearl River, La.	4.64	4.84	6.43	5.47	4.96	5.68	7.71	6.42	5.59	2.88	4.33	4.90	63.85
Reserve, La.	4.49	5.16	5.64	4.92	4.90	5.31	7.00	5.74	5.14	2.96	3.77	5.54	60.57



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NUMBER OF DAYS WITH PRECIPITATION ≥0.01 INCH

FIGURE 10

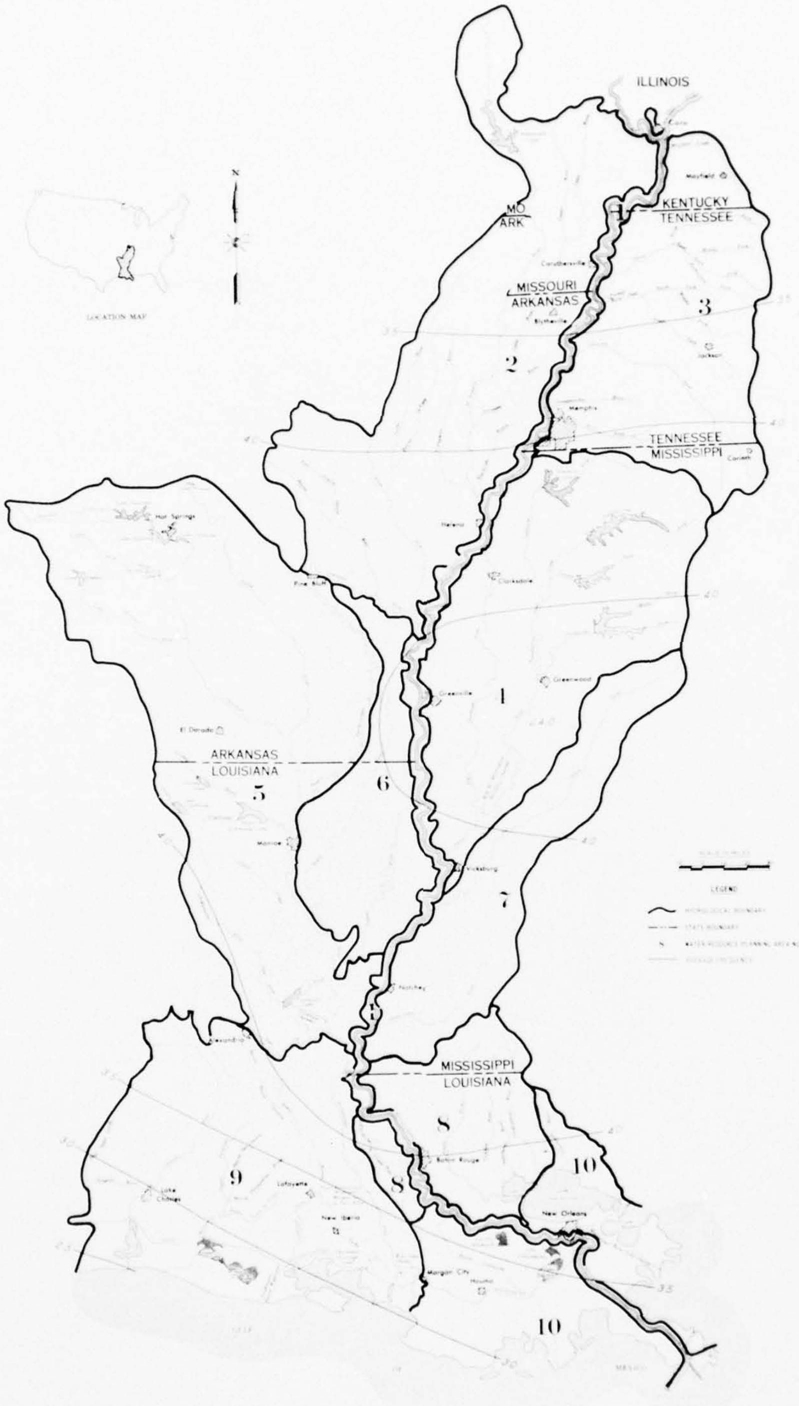


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL NUMBER OF 24-HOUR PERIODS WITH 0.50 INCH OR MORE OF PRECIPITATION

JANUARY, 1931–1960

FIGURE 11

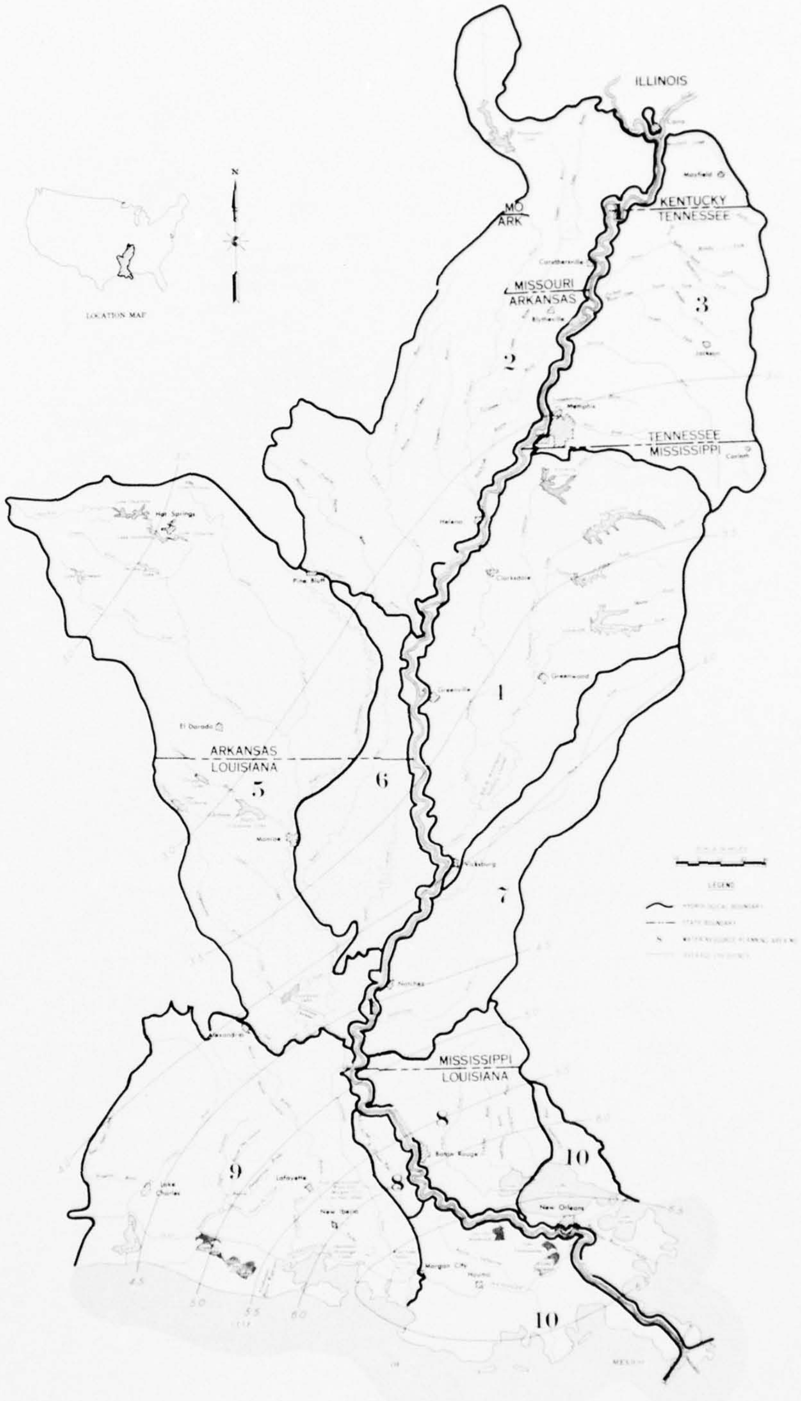


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL NUMBER OF 24-HOUR PERIODS WITH 0.50 INCH OR MORE OF PRECIPITATION

APRIL, 1931-1960

FIGURE 12

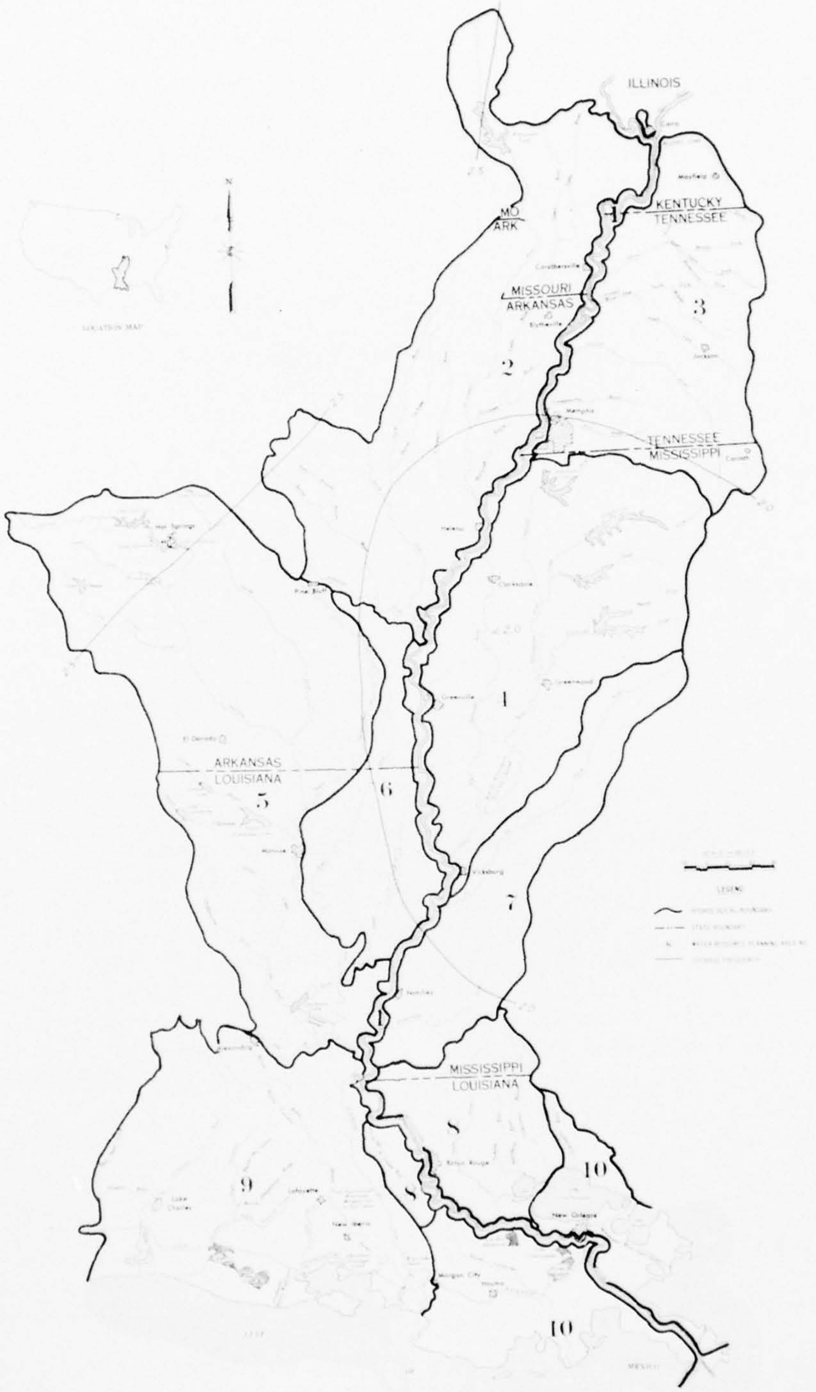


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL NUMBER OF 24-HOUR PERIODS WITH 0.50 INCH OR MORE OF PRECIPITATION

JULY, 1931–1960

FIGURE 13



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL NUMBER OF
24-HOUR PERIODS WITH 0.50 INCH
OR MORE OF PRECIPITATION

OCTOBER, 1931–1960

FIGURE 14

number of occurrences of 0.50-inch rains from a maximum in the coastal regions of southeastern Louisiana both westward along the coast and inland over the Lower Mississippi Region. In October, the occurrences of heavy rains are rare throughout the region, but are most frequent along the northwestern borders.

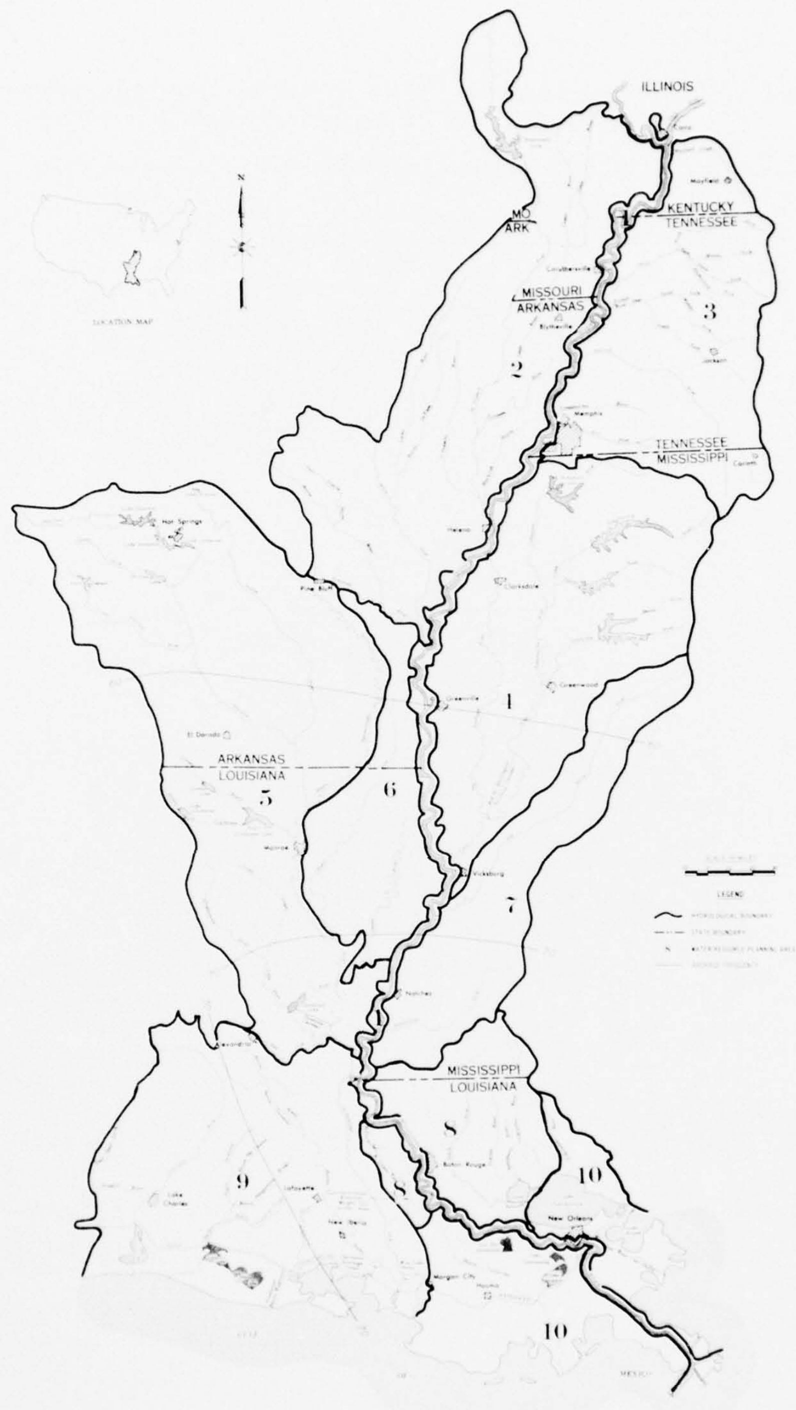
Thunderstorms. A significant portion of the precipitation received over the region is the result of convective thundershower or thunderstorm activity. Figure 15 (143) shows that these convective storms are observed and thunder heard on more than 50 to 60 days per year at points in northern sections of the region and on more than 60 to 70 days from southeastern Arkansas and the lower delta area of Mississippi southward to the Gulf of Mexico. Thunderstorms are less frequent during the winter months. The largest average numbers occur during June, July, and August.

Although thunderstorms are common throughout the region, the occurrence of hail of sufficient size to damage property and crops over large areas is relatively rare. Hail does occur in all sections of the region, producing considerable crop damage, as well as roof, window, and automobile damage. Large hail tends to be associated with squall line activity. Summer air mass thunderstorms only rarely contain hail larger than "pea-size" at the surface, if indeed any at all.

Short period maximum precipitation. The Lower Mississippi Region, because of the convective, frontal, and tropical cyclone influences which operate from time to time, has relatively high precipitation amounts during short time periods. Maximum observed 5-minute through 24-hour precipitation totals for several of the first-order Weather Service stations in and near the region are shown in table 2 (53, 145, 151). Intense rains, 2/3 inch within 5 minutes, 2-1/2 to more than 4-1/2 inches within 1 hour, and 7-1/2 to 16 inches within 24 hours, have been observed throughout the region. Several parts of Weather Bureau Technical Paper No. 15 (151) give similar data for numerous points in the region.

Diurnal variation of precipitation. The variability of precipitation occurrence extends not only through seasonal and monthly patterns but to daily patterns as well: certain hours of the day normally have more frequent rainfall than others at the same place. Regional variations also exist. These patterns result from the combined activity of the various precipitation mechanisms discussed earlier.

Figure 16 illustrates, for New Orleans and Memphis, the diurnal variations in the occurrence of precipitation during each month of the year. Abscissas of the graphs are hours of the day, and ordinates are the percentages of total hours with measurable precipitation during the years 1951 through 1960 (148). Outstanding differences between these



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN ANNUAL NUMBER OF DAYS WITH THUNDERSTORMS

PERIOD OF RECORD THROUGH 1964

FIGURE 15

Table 2 - Observed 5-Minute - 24-Hour Maximum Precipitation in Inches (Period of Record Through 1970)

	Minutes					Hours				
	5	10	15	30	60	2	3	6	12	24
Little Rock	0.63	1.01	1.35	2.07	3.00	4.60	6.82	7.68	8.19	9.58
	7/2	5/10	5/10	6/25	5/26	5/26	5/26	5/26	4/9	4/8
	1939	1930	1930	1946	1955	1955	1955	1955	1913	1913
Cairo	0.65	1.13	1.45	2.08	3.15	4.65	6.20	7.29	7.39	7.56
	5/29	6/12	8/11	8/11	6/28	8/11	8/11	8/11	8/11	8/11
	1945	1958	1952	1952	1905	1952	1952	1952	1952	1952
Baton Rouge	0.67	1.20	1.57	2.07	2.76	3.80	4.97	8.28	11.31	12.08
	4/13	7/2	8/1	7/11	3/3	4/27	4/14	4/14	4/14	4/14
	1966	1966	1959	1967	1970	1962	1967	1967	1967	1967
Lake Charles	0.70	1.34	1.72	2.40	3.95	6.52	9.70	15.38	15.79	16.01
	5/13	4/29	4/29	7/2	6/19	6/19	6/19	6/19	6/19	6/18
	1966	1960	1960	1968	1947	1947	1947	1947	1947	1947
New Orleans	1.00	1.48	1.90	3.18	4.71	5.87	6.54	8.62	12.76	14.01
	2/5	4/25	4/25	4/25	4/25	4/25	4/15	9/6	4/15	4/15
	1955	1953	1953	1953	1953	1953	1927	1929	1927	1927
Shreveport	0.76	1.29	1.74	2.28	3.15	5.19	6.49	7.54	8.52	12.44
	6/25	6/25	6/25	8/28	5/13	7/23	7/23	7/23	7/24	7/24
	1932	1932	1932	1940	1908	1905	1905	1905	1933	1933
Jackson	0.77	1.54	2.00	2.26	2.56	3.43	4.15	4.87	5.60	7.50
	3/3	3/3	3/3	8/10	8/10	5/1	12/27	12/27	12/27	12/26
	1964	1964	1964	1966	1966	1954	1942	1942	1942	1942
Vicksburg	0.83	1.20	1.41	2.44	3.44	4.17	5.78	7.10	8.73	9.97
	4/12	5/12	8/19	8/22	8/22	2/17	2/17	7/13	4/29	3/27
	1909	1923	1918	1960	1960	1927	1927	1907	1953	1951
Memphis	0.78	1.27	1.71	2.80	3.25	4.70	5.00	7.03	9.67	10.48
	3/9	7/16	7/16	7/16	7/16	7/16	7/16	11/21	11/21	11/20
	1901	1929	1929	1929	1929	1929	1929	1934	1934	1934

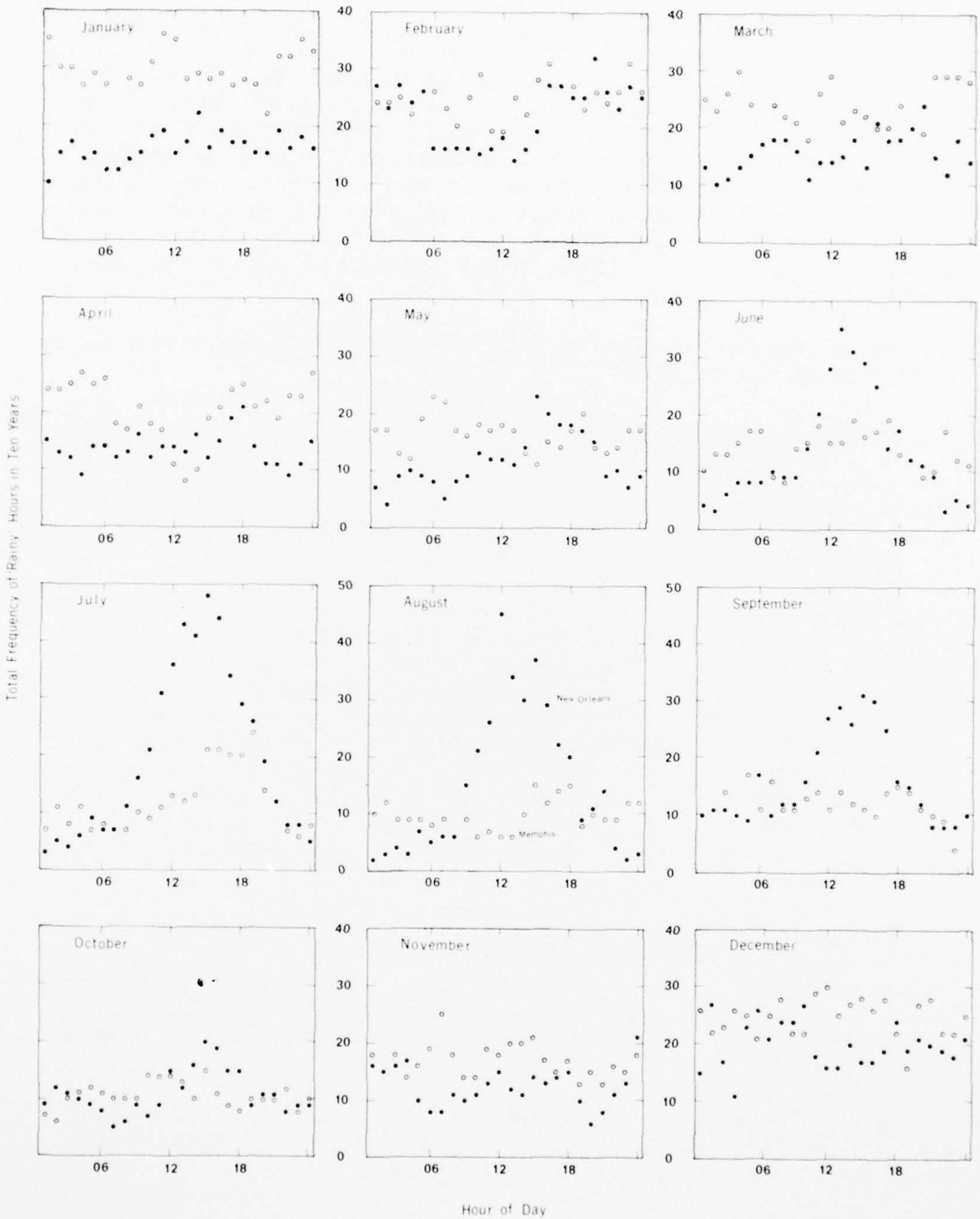


Figure 16. Diurnal Distributions of Measurable Precipitation, by Months, New Orleans, Louisiana, and Memphis, Tennessee, 1951-1960

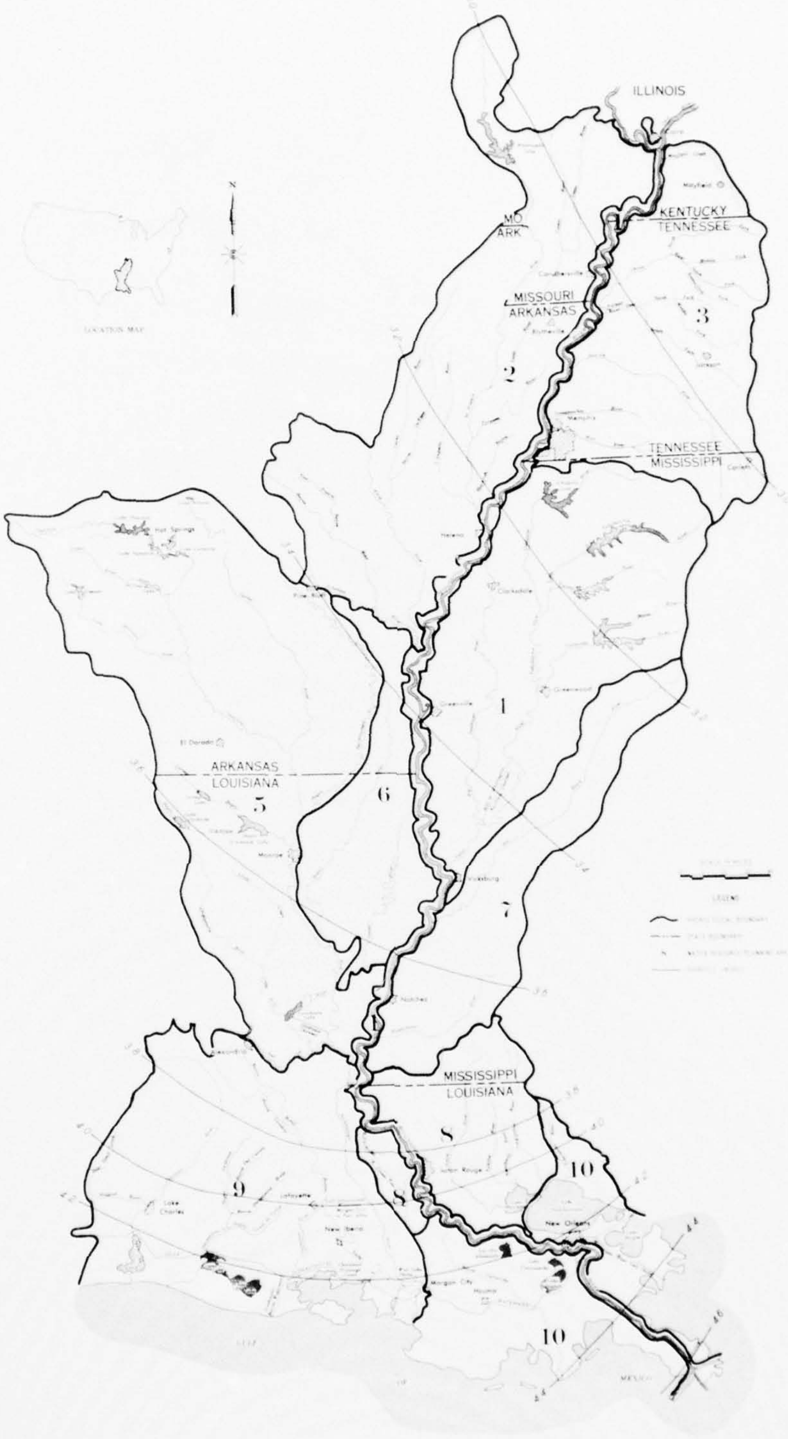
northern and southern locations in the Lower Mississippi Region are (1) the strong afternoon maximum of rainfall during the warmer months at New Orleans, reflecting the occurrence of the common airmass thundershowers there; this aspect is strongly damped at Memphis; (2) the relative diurnal uniformity of cool season precipitation at both locations, although the frequency is substantially higher at Memphis, reflecting more frequent frontal and cyclonic rainfall; and (3) the paucity of precipitation occurrences at Memphis during August, September, and October--displaced in time at New Orleans to October and November, reflecting variations in the duration of the autumn transitional period.

Riley (89) has examined the diurnal precipitation patterns in the delta area of Mississippi.

Rainfall frequency-depth-duration studies and atlases. Statistical analyses of rainfall data for the primary purpose of presenting them in a manner convenient for hydrologic analysis, engineering design and economic analysis have long been the task of the Office of Hydrology, National Weather Service. Numerous technical papers have been prepared to disseminate this important specialized information (44, 62, 68, 152, 153, 154, 155, 156, 157). Figures 17 and 18 (44) are samples of these analyses. The probability (expressed as a return period) of the depth of precipitation, in inches, which can be expected to occur within a specified duration in hours is shown in these figures. These charts are for point rainfalls, and values may be interpolated. According to these analyses, the heaviest rainfalls on all time scales occur in the coastal regions. The seasonal variations of the probable maximum precipitation, defined as the depth-duration-area rainfall relationships that could result if meteorological conditions experienced during an actual storm in a certain area were maximized to the fullest extent probable, are shown in U. S. Weather Bureau Hydrometeorological Report No. 33 (157).

Precipitation probabilities. Probabilities of receiving specific monthly amounts of precipitation in standard Weather Service climatological divisions in the eastern United States, using the gamma probability function (112), have been developed (109). The entire Lower Mississippi Region is included. Some State studies (59, 83) have also been completed.

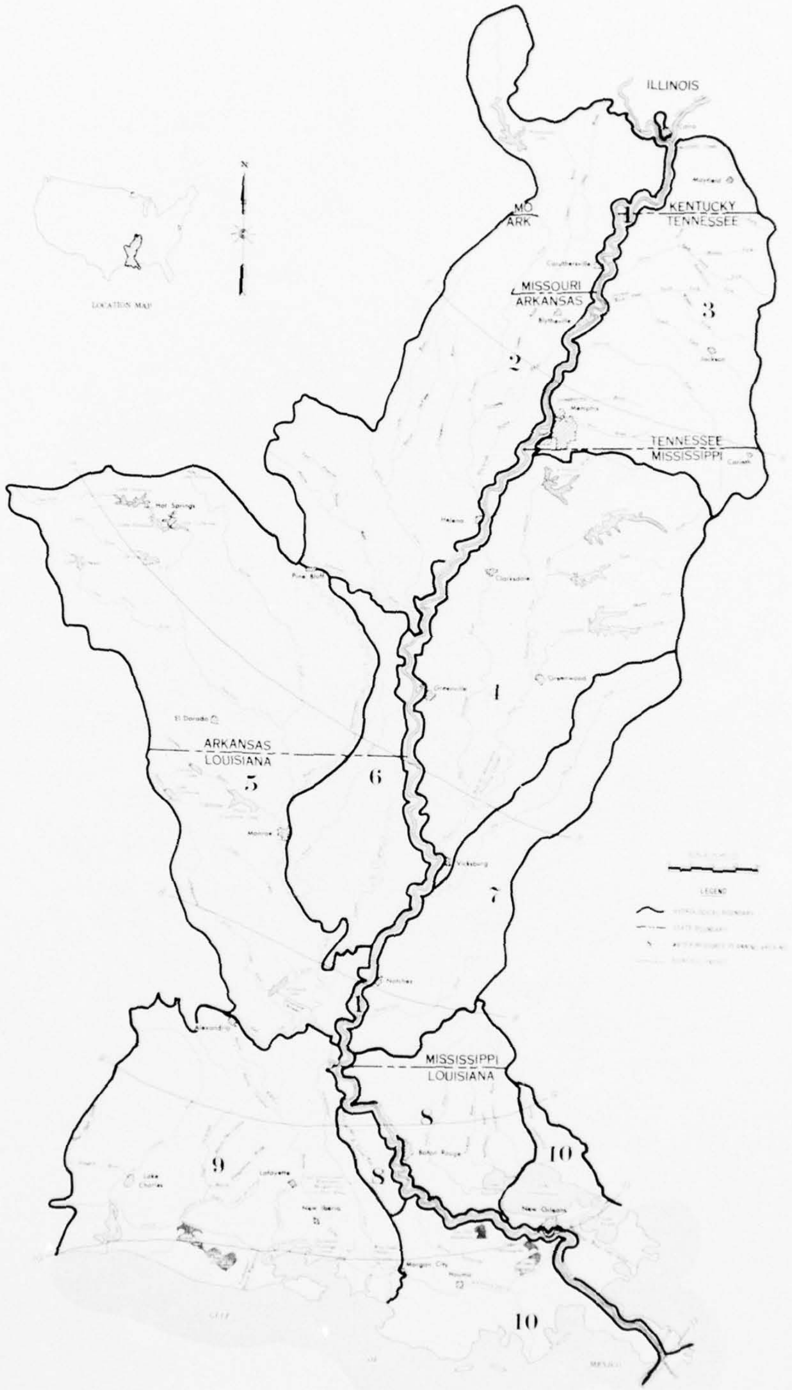
Snow, sleet, glaze. Snow and sleet are minor climatic elements over most of the Lower Mississippi Region. Figure 19, adapted from the Climatic Atlas of the United States (141), shows that the mean annual total snowfall ranges from 6 to 12 inches in southeastern Missouri to nearly 2 inches along the Louisiana-Arkansas border, to less than 1 inch from central Louisiana southward. Snow falls in measurable amounts annually in northern portions of the region, and in almost 80 percent of all record years in Louisiana. Snow is much less frequent



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

ISOPLUVIAL MAP OF FIFTY-YEAR ONE-HOUR RAINFALL, INCHES

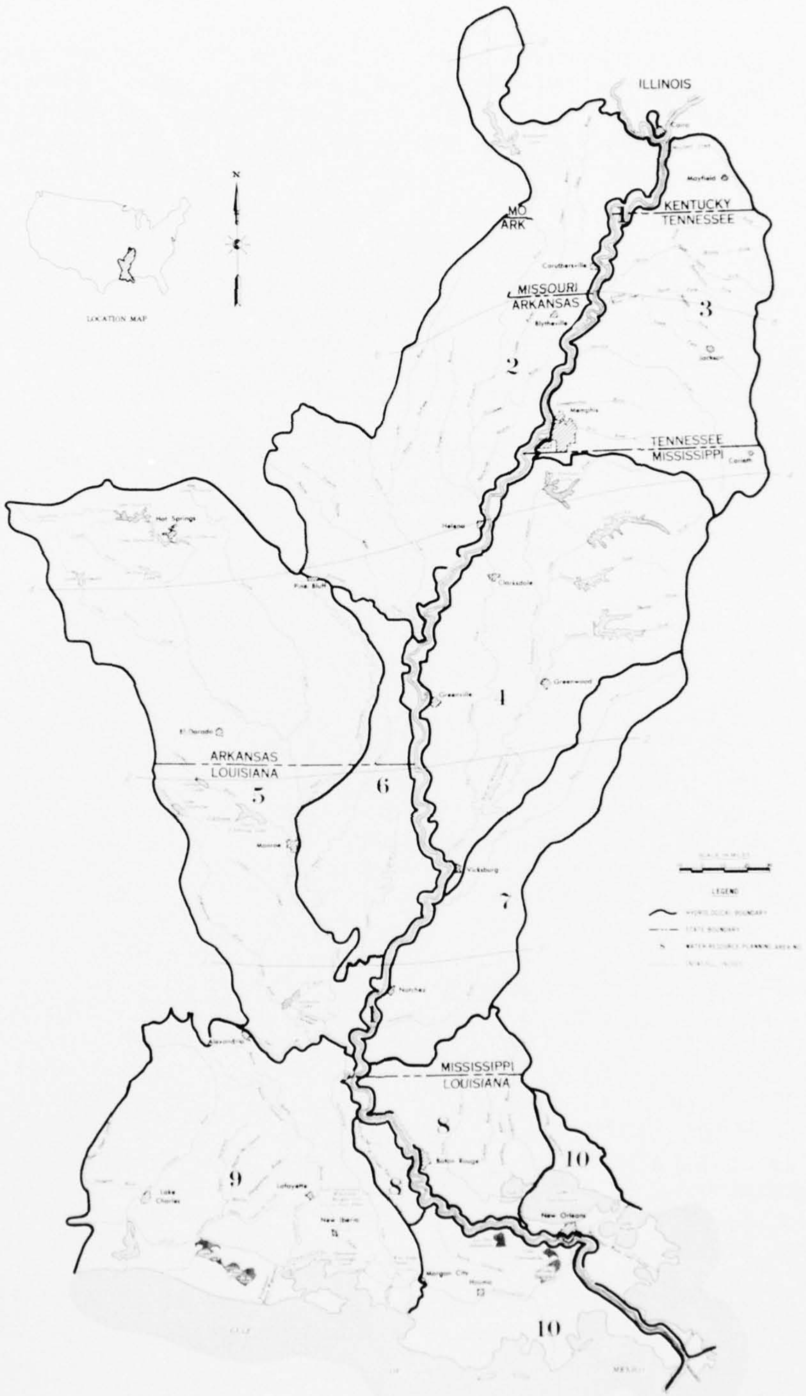
FIGURE 17



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

ISOPLUVIAL MAP OF FIFTY-YEAR TWELVE-HOUR RAINFALL, INCHES

FIGURE 18



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN ANNUAL SNOWFALL, INCHES

PERIOD OF RECORD THROUGH 1960

FIGURE 19

in southern Louisiana, but the largest single-storm 1-day amounts for the entire Lower Mississippi Region occurred during mid-February 1895 in southwest Louisiana. Snow depths reached 24 inches at Rayne and 22 inches at Lake Charles. Snow seldom remains on the ground for more than a week in northern sections or for more than a day or two in southern areas.

Freezing rain (glaze), which forms a coating of clear ice on exposed objects, occurs over the region with about the same frequency as snow. These ice storms reach damaging intensity over some northern portions of the region once in 3 to 6 years, and have extended southward to Louisiana coastal sections on rare occasions.

Temperature

Introduction. Temperature is probably the most discussed climatic element. It is also the most popular indicator of climate. Differences in temperature are also the ultimate cause for the air motions which bring about the various states of weather.

Defined in general rather than physical terms, temperature is the degree of hotness or coldness as measured on some definite temperature scale by means of any of several types of thermometers (52).

Annual, seasonal, and monthly temperatures. The normal or mean annual temperature pattern over the Lower Mississippi Region is shown in figure 20 (from 141). This pattern is basically latitudinal, with some modification due to microclimatic effects and the regional distributions of land and water. The annual temperature really tells little about the actual climate of a region, since measurement of the seasonal variations or the ranges of temperature is not possible.

Normal daily maximum, minimum, and average temperatures for January and July (141) are shown in figures 21 and 22. Winters are usually relatively mild in the region, with January temperatures that average between 40° and 55° F. The daily range of temperature exceeds 20° F in the central sections of the region, and varies between 15° and 20° F both to the north and to the south. These averages, too, are somewhat deceptive, for even in January the region is covered for considerable periods with warm, humid maritime tropical air flowing northward from the Gulf of Mexico and the tropical Atlantic. During shorter periods, the region is also dominated by very cold, dry continental arctic air. These sharp airmass contrasts make winter a season of strong temperature variability. The "typical" winter day is consequently difficult to characterize, because it is not simply specified by the average maximum and minimum temperatures for the month.

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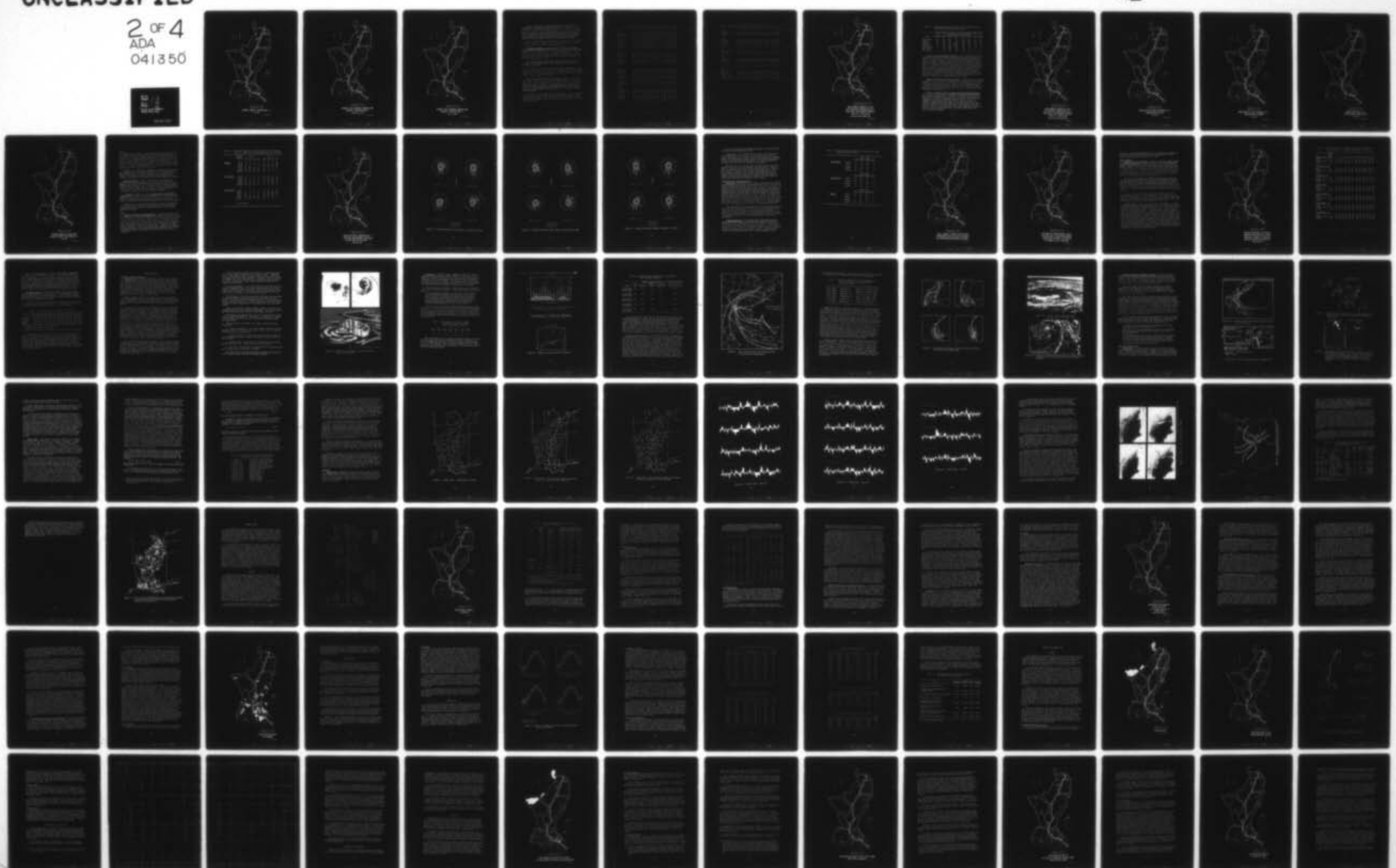
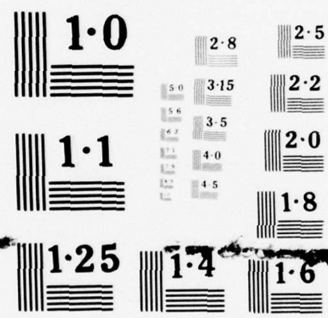
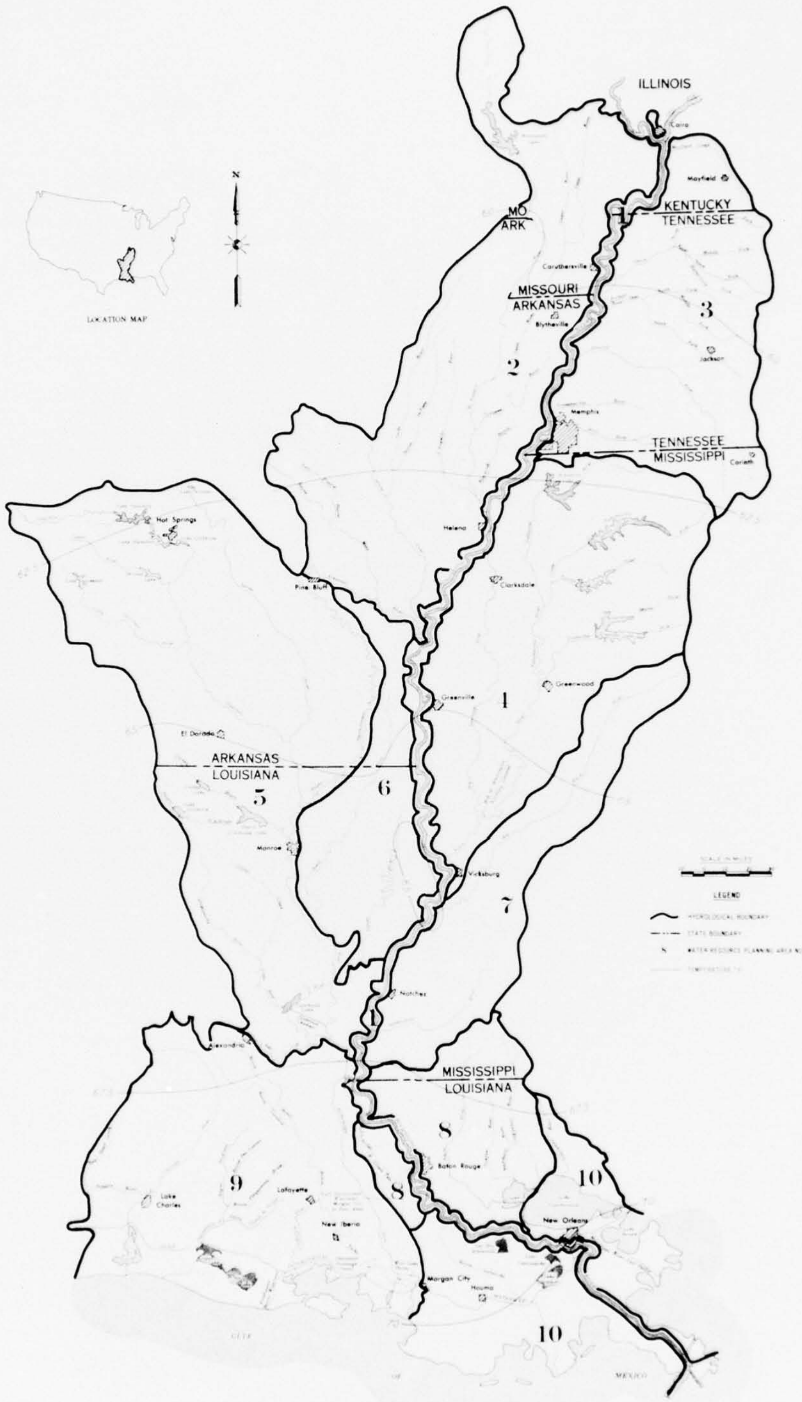




NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

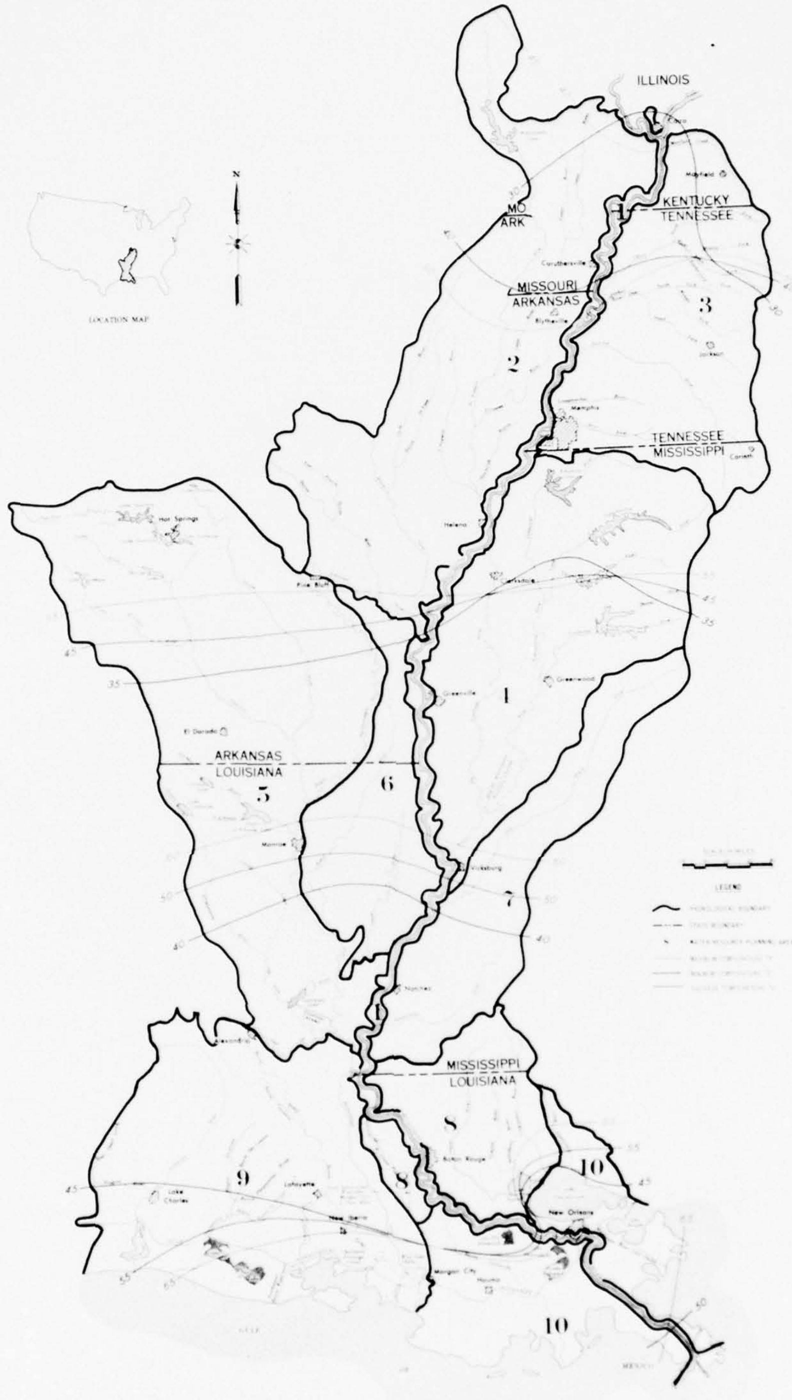


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL ANNUAL TEMPERATURE, °F

1931-1960

FIGURE 20

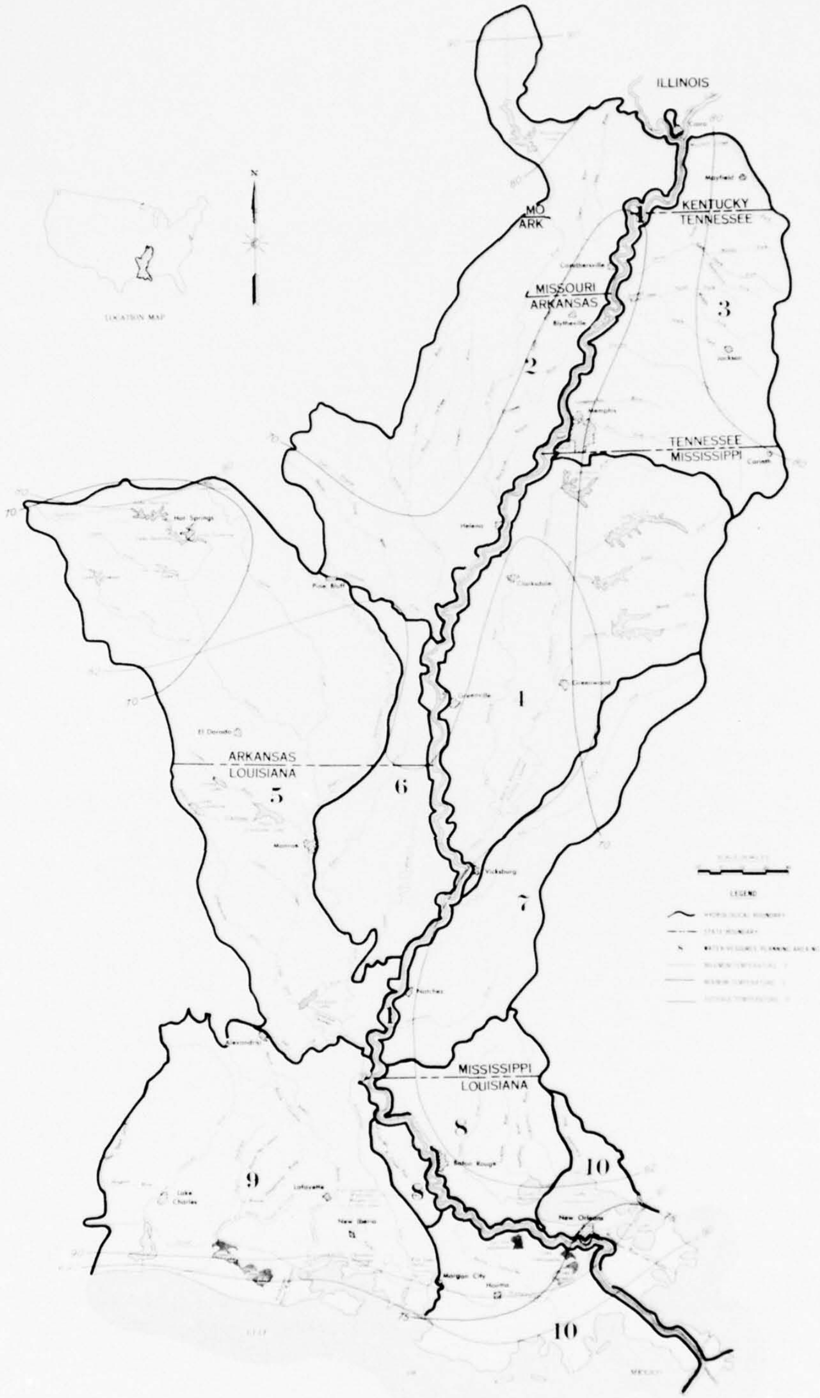


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES, °F

JANUARY, 1931–1960

FIGURE 21



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES, °F

JULY, 1931-1960

FIGURE 22

Summers in the Lower Mississippi Region are distinctly hot; average July temperatures usually range between 78° and 82° F. The daily range of summer temperatures exceeds 20° F in the northern half of the region, and scales downward to nearly 10° F along the immediate coast of Louisiana. Absolute and relative humidity are also high. This combination of heat and humidity produces periods of oppressive sultry weather with little cooling power. The usual summer heat in much of the region resembles that of the tropical wet climates.

Table 3 shows monthly and annual normal temperatures for selected sites in each WRPA. The data (from 149) are for the 30-year climatological standard normal period, 1931 through 1960.

Temperature extremes. All portions of the Lower Mississippi Region exhibit strong continentality relative to extreme minimum temperatures (142). Readings below -20° F have been noted as far south as Tennessee and adjacent sections of Arkansas; temperatures of 0° F or lower have extended into northern Louisiana and central Mississippi; and all sections along the immediate Gulf Coast have experienced minimum temperatures of 10 to 20° F.

The extreme maximum temperature range over the region is 100 to 120° F. The coastal region, with a stronger marine influence, has the lower extremes.

The occurrence of both unusually high and low temperatures is possible only when anomalies in the usual circulation patterns allow the intrusion of: (1) dry continental air with marked subsidence in summer, and (2) massive outbreaks of rapidly moving and unmodified arctic air in winter. These situations are rare.

Days with various temperature thresholds. Figure 23 shows the mean number of days per year with a maximum temperature of 90° F and above and a minimum temperature of 32° F and below (141). The moderating influence of the Gulf of Mexico and the effects of latitude are reflected in the low frequency of high temperatures in the coastal area; in the rapid increase in the number of freezes inland from the coast; and in the maximum of days above 90° F over interior Louisiana and Mississippi.

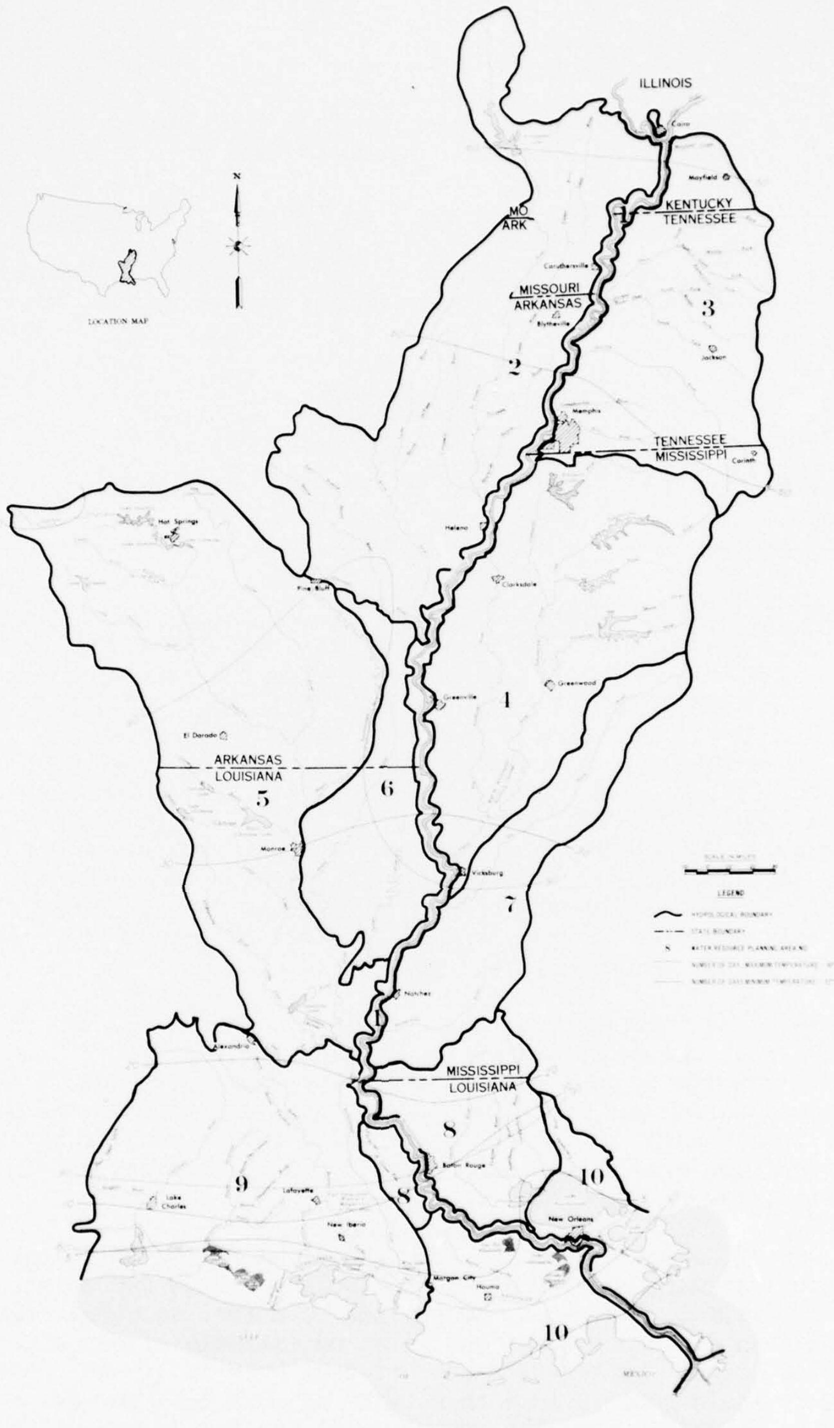
The data in table 4 amplify these observations. Table 4 gives the average number of hours per year with temperatures exceeding various threshold temperatures (148). The interior stations exhibit substantially greater numbers of both higher and lower temperatures than those nearer the coast.

Table 3 - Monthly and Annual Normal Temperatures at Selected Stations, °F., 1931-1960

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
WRPA 2													
Arcadia, Mo.	33.5	36.5	44.0	55.7	64.1	73.0	77.0	76.1	68.5	57.8	44.7	36.1	55.6
Greenville 4 NNW, Mo.	36.0	39.0	46.3	57.4	65.4	74.3	78.2	77.3	69.7	58.7	45.8	37.7	57.2
Marble Hill, Mo.	35.6	38.8	46.4	57.7	66.0	74.9	78.6	77.7	70.1	59.1	45.8	37.1	57.3
Sikeston SE Mo. Research	36.8	39.4	47.2	58.4	67.9	77.1	80.2	79.0	71.8	61.0	47.1	38.5	58.7
Blytheville, Ark.	40.0	43.0	50.4	61.2	70.2	78.6	81.3	80.3	73.5	63.1	49.9	41.9	61.1
Brinkley, Ark.	42.6	45.4	52.5	62.2	70.3	78.4	81.3	80.8	74.1	63.4	50.9	43.8	62.1
Corning, Ark.	38.7	41.6	49.6	60.4	68.9	77.6	81.0	80.0	72.7	61.6	48.6	40.4	60.1
Helena, Ark.	43.5	46.4	53.2	62.8	70.9	78.7	81.5	81.1	75.1	65.0	52.4	45.1	63.0
Jonesboro, Ark.	40.4	43.3	50.7	61.3	69.7	78.3	81.4	80.6	73.7	63.1	50.1	42.1	61.2
Marianna 2 S, Ark.	42.4	45.1	52.3	62.0	70.4	78.5	81.0	80.2	73.8	63.4	51.2	44.0	62.0
Marked Tree, Ark.	39.3	41.9	49.6	60.5	69.5	78.0	80.9	79.9	72.8	62.0	48.8	41.1	60.4
Newport, Ark.	41.2	44.1	51.6	61.9	70.2	78.6	81.8	81.0	73.9	63.2	50.4	42.9	61.7
Searcy, Ark.	41.6	44.5	51.6	61.8	69.8	78.0	81.7	81.3	74.5	63.6	49.4	43.2	61.8
Stutgart, Ark.	43.7	46.4	53.4	63.0	71.0	79.1	82.3	81.9	75.5	64.8	52.3	45.3	63.2
Little Rock WSO, Ark.	40.6	44.4	51.8	62.4	70.5	78.9	81.9	81.3	74.3	63.1	49.5	41.9	61.7
WRPA 3													
Bolivar 2, Tenn.	41.3	43.9	50.9	61.0	68.8	76.8	79.9	79.2	72.7	61.6	49.6	42.7	60.7
Brownsville, Tenn.	41.5	44.1	51.4	61.6	69.8	77.9	80.6	79.8	73.0	63.0	50.8	43.2	61.4
Covington, Tenn.	41.1	43.7	50.6	60.8	69.6	78.0	80.8	79.9	73.1	62.7	50.3	42.7	61.1
Jackson ES, Tenn.	40.6	43.2	50.1	60.2	68.4	76.7	79.5	78.8	72.1	61.5	49.2	42.2	60.2
Memphis WSO, Tenn.	41.5	44.1	51.1	61.4	70.3	78.5	81.3	80.5	73.9	63.1	50.1	42.5	61.5
Milan, Tenn.	40.4	43.1	50.4	60.5	68.8	77.1	80.0	79.2	72.5	61.8	49.5	40.7	60.3
Moscow, Tenn.	42.0	44.6	51.6	61.4	69.2	76.9	80.0	79.4	72.7	62.2	50.3	43.4	61.1
Newbern, Tenn.	39.7	42.4	49.8	60.6	69.4	77.7	80.4	79.7	73.0	62.6	49.5	41.6	60.5
Samberg, Tenn.	38.3	40.9	48.8	59.9	69.0	77.5	80.6	79.6	72.2	61.3	48.3	40.1	59.7
Union City, Tenn.	37.6	39.9	47.3	58.4	67.8	76.6	79.6	78.9	71.6	60.3	47.4	39.4	58.7
Corinth, Miss.	43.2	45.6	52.5	62.6	71.0	78.9	81.7	81.2	74.9	64.1	51.5	44.6	62.7
WRPA 4													
Batesville, Miss.	43.8	46.6	53.2	62.9	70.9	78.5	81.2	80.7	74.5	63.7	51.8	45.0	62.7
Belzoni, Miss.	46.9	49.9	56.4	65.1	73.1	80.2	82.4	82.0	76.1	66.0	54.1	48.1	65.0
Clarksdale, Miss.	45.2	48.1	55.1	65.0	73.4	81.1	83.4	83.0	76.9	66.5	53.7	46.5	64.8
Greenville, Miss.	46.2	48.9	55.5	64.5	72.6	79.9	82.3	82.0	76.2	66.4	54.1	47.3	64.7
Greenwood FAA, Miss.	46.4	49.2	55.7	64.7	72.9	80.2	82.5	82.1	76.0	65.5	53.4	47.3	64.7
Holly Springs 2N, Miss.	42.7	45.1	52.0	61.9	69.9	77.8	80.7	80.2	73.9	63.6	51.3	44.1	61.9
Moorhead, Miss.	46.1	48.9	55.4	64.5	72.6	80.0	82.3	81.3	75.6	64.9	53.3	47.3	64.4
Pontotoc, Miss.	44.5	47.0	53.7	63.0	70.8	78.4	80.8	80.6	74.8	64.7	52.4	45.6	63.0
Scott, Miss.	44.2	47.1	53.8	63.4	71.8	79.3	81.6	81.1	75.1	62.8	52.5	45.6	63.2
Stoneville, ES, Miss.	46.1	48.7	55.1	64.0	71.9	79.3	81.7	81.2	75.5	65.2	53.5	47.2	64.1
University, Miss.	44.2	46.9	53.7	63.3	70.9	78.6	81.0	81.0	75.0	64.7	52.3	45.6	63.1
Vicksburg, Miss.	49.0	51.8	57.6	65.7	73.4	79.7	81.8	81.7	76.6	67.5	56.2	50.3	65.9
Water Valley, Miss.	44.8	47.5	53.7	62.9	70.4	78.2	81.1	80.7	74.7	64.4	52.8	46.0	63.1
Yazoo City 5 NNE, Miss.	47.6	50.3	56.7	65.3	73.0	80.0	82.3	82.0	76.7	66.5	54.6	48.7	65.2
WRPA 5													
Camden 1, Ark	44.7	47.9	54.5	63.9	71.6	79.4	82.4	81.9	75.5	64.9	52.6	46.0	63.8
Crossett 7 S, Ark.	46.3	49.2	55.5	63.8	71.2	78.7	81.3	81.3	75.9	65.6	53.7	47.3	64.2
Eldorado FAA, Ark.	46.5	49.4	55.6	64.5	72.2	80.0	82.7	82.5	76.6	66.2	54.1	47.6	64.8
Hope 3 NE, Ark.	43.7	46.6	53.2	62.8	70.7	78.8	82.0	82.0	75.6	64.9	52.0	45.2	6[illegible].1
Hot Springs 1 NNE, Ark.	44.2	47.2	54.1	64.0	71.3	79.4	82.8	83.0	76.3	66.1	52.8	45.7	63.9
Mount Ida, Ark.	41.4	44.1	50.5	60.4	68.0	76.4	80.2	79.7	72.7	62.0	49.5	42.7	60.6
Pine Bluff, Ark.	45.1	48.0	54.8	64.5	72.0	79.9	83.1	83.2	76.9	66.3	53.7	46.6	64.5
Portland, Ark.	46.0	48.7	55.1	63.9	71.6	79.1	81.7	81.2	75.2	65.0	53.6	47.5	64.1
Prescott, Ark.	44.6	47.7	54.7	64.1	71.9	79.8	83.1	82.8	76.4	66.0	53.0	46.0	64.2
Calhoun, La.	49.0	51.8	57.6	65.4	72.9	80.2	82.7	82.6	77.1	67.2	55.9	50.1	66.0
Urania, La.	50.0	52.8	58.6	66.1	73.2	80.2	82.6	82.4	77.2	67.2	56.3	50.8	66.5

Table 3 - Monthly and Annual Normal Temperatures at Selected Stations, °F., 1931-1960 (Con.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
WRPA 6													
Dumas 1 ESE, Ark.	45.3	47.8	54.6	63.8	71.9	80.1	83.0	82.4	75.9	65.2	53.0	46.3	64.1
St. Joseph ES, La.	49.9	52.6	58.1	65.5	72.8	79.4	81.5	81.1	76.1	66.4	55.9	50.9	65.9
Tallulah, La.	48.6	51.5	57.4	65.1	72.0	78.8	80.9	80.4	75.1	65.1	54.6	49.4	64.9
Winnsboro, La.	49.6	52.1	58.2	65.9	73.3	80.3	82.7	82.6	77.2	67.3	56.1	50.6	66.3
WRPA 7													
Canton, Miss.	48.3	50.7	56.5	64.5	72.2	79.2	81.5	81.2	76.0	66.0	54.7	49.3	65.0
Eupora, Miss.	46.1	48.5	54.5	63.1	70.8	78.3	80.7	80.2	74.7	64.7	53.0	46.7	63.4
Jackson WSO, Miss.	48.0	50.7	56.4	64.4	72.5	79.4	81.6	81.3	76.2	66.5	54.9	49.0	65.1
Kosciusko, Miss.	46.3	48.7	55.1	63.5	71.4	78.6	80.9	80.7	75.2	65.3	53.5	47.3	63.9
Natchez, Miss.	51.0	53.8	59.0	66.5	73.5	80.1	82.0	81.9	77.3	68.0	57.2	52.2	66.9
Port Gibson, Miss.	48.5	51.5	57.3	64.7	72.1	78.7	81.0	80.6	75.4	65.5	54.4	49.2	64.9
Utica, Miss.	50.0	52.6	58.0	65.6	73.1	80.0	82.1	81.9	77.2	67.6	56.5	51.0	66.3
WRPA 8													
Baton Rouge WSO, La.	52.9	55.4	60.7	68.2	74.8	80.9	82.7	82.4	77.9	69.1	58.9	53.7	68.1
Cinclare, La.	54.1	56.6	61.3	68.3	75.0	80.9	82.3	82.1	78.2	69.6	59.4	55.0	68.6
Donaldsonville, La.	55.6	57.7	62.3	69.0	75.7	81.2	82.4	82.5	79.1	71.0	69.9	56.5	69.5
WRPA 9													
Bunkie, La.	51.8	54.5	59.5	67.1	74.2	80.6	82.4	82.0	77.4	68.5	57.8	52.8	67.4
Elizabeth 1 NW, La.	51.8	54.5	59.8	67.3	74.5	80.8	82.6	82.7	78.1	69.3	58.2	53.0	67.7
Jennings, La.	54.2	56.7	61.4	68.4	75.2	81.3	82.7	82.5	78.8	70.6	60.0	55.2	68.9
Lafayette FAA, La.	53.6	56.2	60.9	68.1	74.9	80.8	82.2	82.0	78.1	69.6	59.3	54.8	68.4
Lake Charles, La.	53.7	56.3	61.1	67.9	75.6	81.2	82.3	82.2	78.7	70.5	59.6	54.6	68.6
Melville, La.	53.3	55.9	60.9	67.9	74.5	80.6	82.2	82.0	77.6	68.9	58.8	54.3	68.1
Ville Platte 2 SW, La.	52.8	55.5	60.3	67.6	74.8	80.9	82.5	82.3	77.9	69.2	58.7	53.9	68.0
WRPA 10													
Burrwood WSO, La.	57.5	58.7	62.0	68.4	75.6	81.6	83.2	83.8	81.5	74.8	65.1	59.7	71.0
Covington 4 NNW, La.	53.6	55.8	60.3	67.2	74.1	79.9	81.3	81.0	77.3	68.9	58.8	54.3	67.7
Houma 1 SW, La.	56.5	58.6	62.4	68.9	75.1	80.2	81.6	81.6	78.3	70.4	61.0	57.2	69.3
Morgan City, La.	56.0	58.3	62.4	69.0	75.6	81.1	82.2	82.2	78.9	71.0	61.0	56.8	69.5
New Orleans WS City, La.	56.0	58.2	62.8	69.7	76.8	82.3	83.4	83.5	80.2	72.6	62.0	57.1	70.4
New Orleans WS Moisant, La.	54.6	57.1	61.4	67.9	74.4	80.1	81.6	81.9	78.3	70.4	60.0	55.4	68.6
New Orleans WS Audubon, La.	55.5	57.7	62.1	68.9	75.7	81.1	82.6	82.5	78.9	71.1	61.0	56.6	69.5
Reserve, La.	53.8	55.9	60.6	67.8	75.1	81.0	82.5	82.3	78.7	70.4	59.8	54.6	68.5



LOWER COMPREHENSIVE REGION
COMPREHENSIVE STUDY

MEAN ANNUAL NUMBER OF DAYS WITH MAXIMUM TEMPERATURE 90° F AND ABOVE, AND MINIMUM TEMPERATURE 32° F AND BELOW

PERIOD OF RECORD THROUGH 1904

FIGURE 23

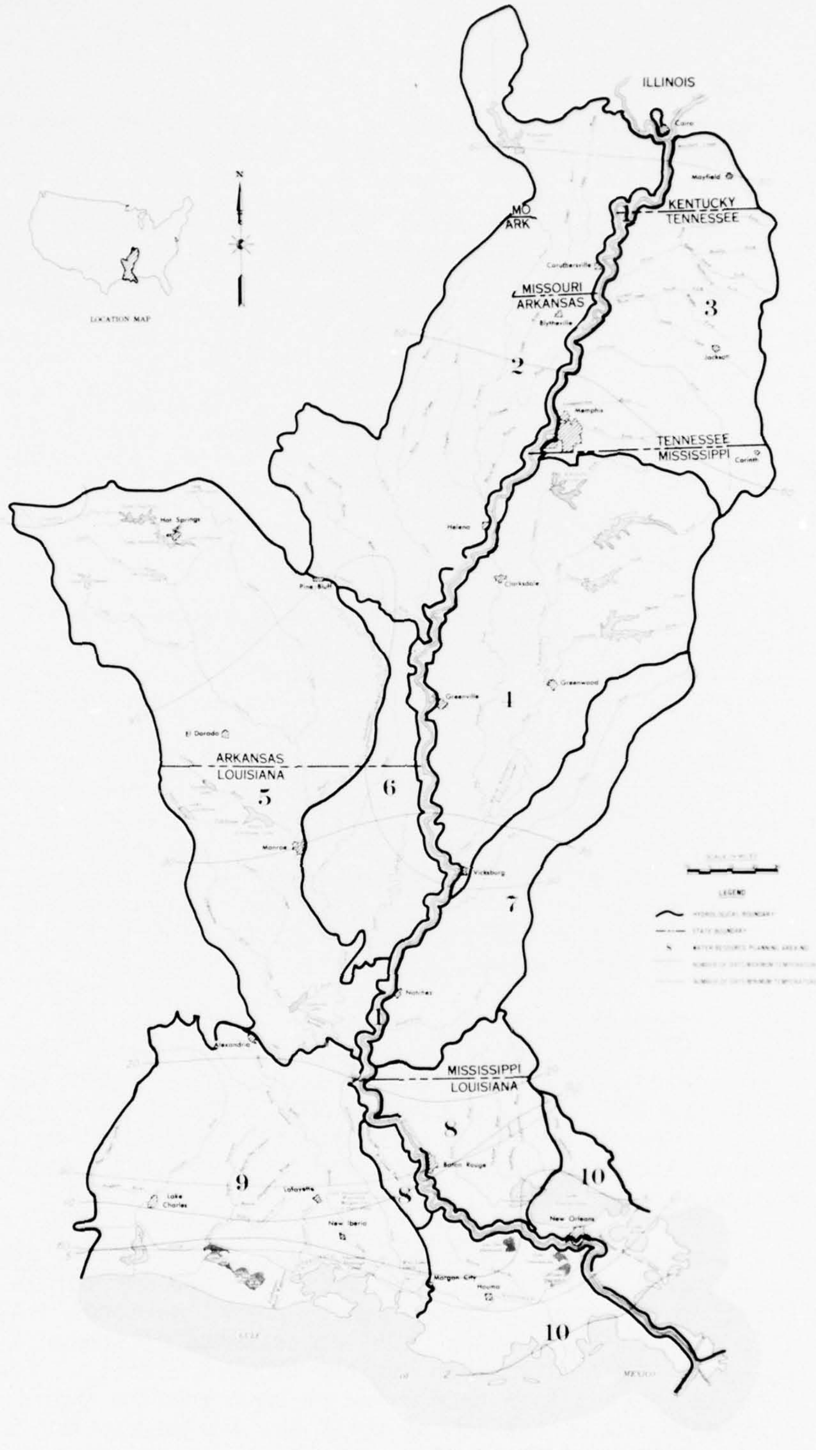
Table 4 - Average Number of Hours Per Year with Temperatures Above and Below Specified Threshold Values

Site	Average Number of Hours Per Year with Temperatures Above and Below Threshold Values							
	≥100°F	≥95°F	≥90°F	≥85°F	≤34°F	≤29°F	≤24°F	≤19°F
Little Rock	25	132	445	950	514	251	79	29
Memphis	18	120	428	917	683	309	113	39
Shreveport	26	149	543	1,126	303	103	31	18
Jackson	14	113	402	1,092	379	155	52	11
Baton Rouge	1	47	401	1,001	166	49	11	4
Lake Charles	1	38	348	992	94	22	5	3
New Orleans		12	241	862	58	11	2	2

Freezes, average dates and frequencies. The occurrence of freezing temperatures has adverse effects on many industrial and commercial activities, and freezes are one of the significant hazards faced by agriculture. Figures 24 and 25 (adapted from 141) show mean dates of the initial 32°F day in autumn and the final 32°F day in spring; figure 26 depicts the duration of the freeze-free period. The "growing season" is long, i.e., from 6 to 7 months in northern portions of the region and from 8 to almost 12 months in southern sections. As indicated, in some years northern and central Louisiana and the area southward may be freeze-free. Although below-freezing temperatures can occur during a period of several months each season, during the average winter, they are actually observed on from 5 nights in the southern part of the region to 70 nights in the northern part of the region.

Degree days (heating, cooling, growing). The degree day is defined as a measure of the departure of the mean daily temperature from a given standard: one degree day for each degree of departure above (or below) the standard during one day (52). Degree days are accumulated over a "season" at any point during which the total can be used as an index of past temperature effect upon some quantity, such as plant growth, fuel consumption, power usage, etc.

Figure 27, adapted from the Climatic Atlas of the United States (141), shows normal annual heating and cooling degree day totals for the Lower Mississippi Region. Comparison of normal seasonal heating degree days in different locations gives an estimate of seasonal fuel consumption, since the relationship between these is linear. For example, it would require more than twice as much fuel to heat a building in Memphis, where the annual total heating degree day total is 3232, than to heat a similar building in New Orleans, where the degree day total is less than 1400. The cooling degree day concept is used in a similar fashion to estimate the power requirements for air-conditioning equipment.

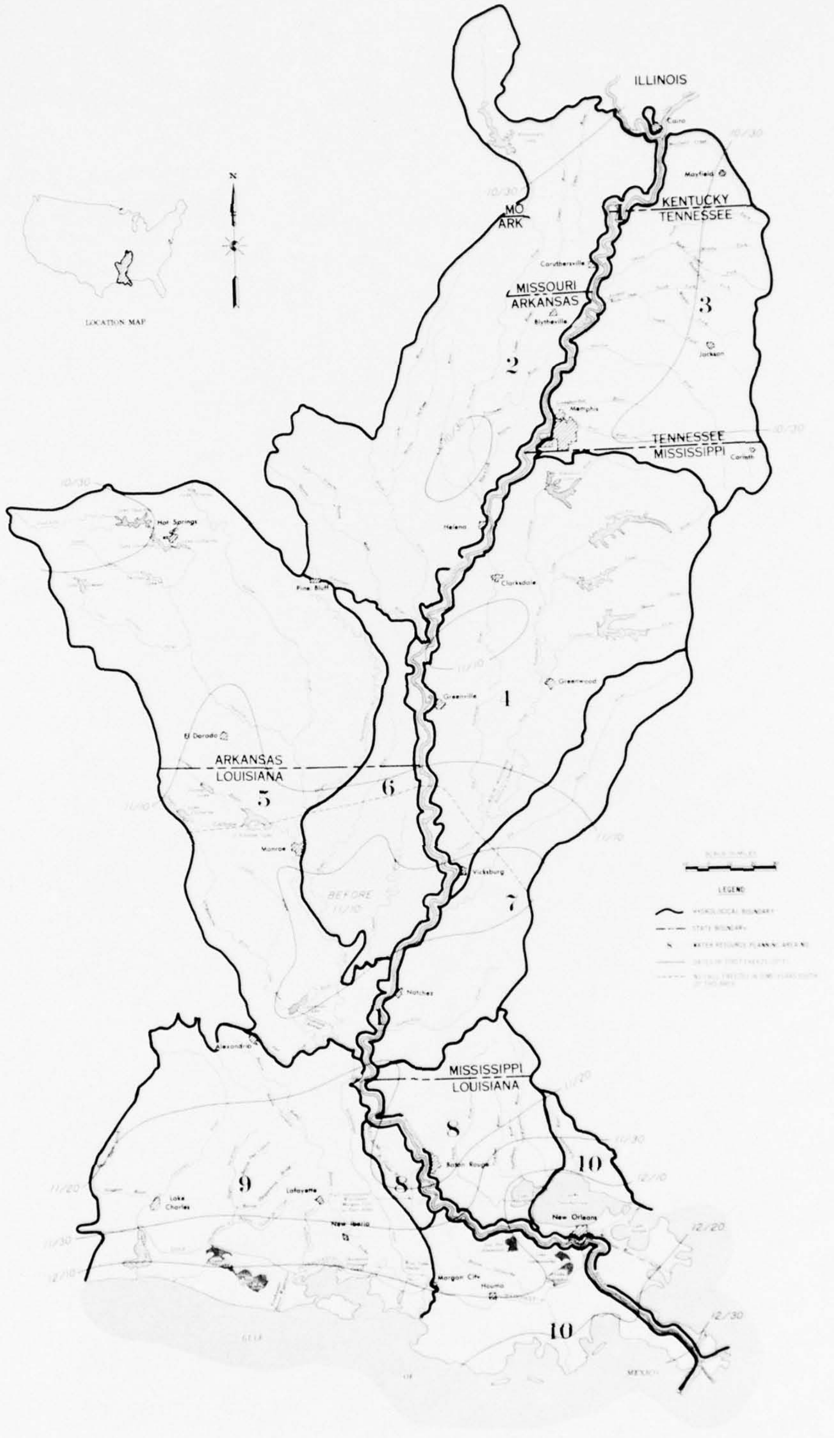


LOWER COMPREHENSIVE REGION
COMPREHENSIVE STUDY

MEAN ANNUAL NUMBER OF DAYS WITH MAXIMUM TEMPERATURE 90° F AND ABOVE, AND MINIMUM TEMPERATURE 32° F AND BELOW

PERIOD OF RECORD THROUGH 1904

FIGURE 23

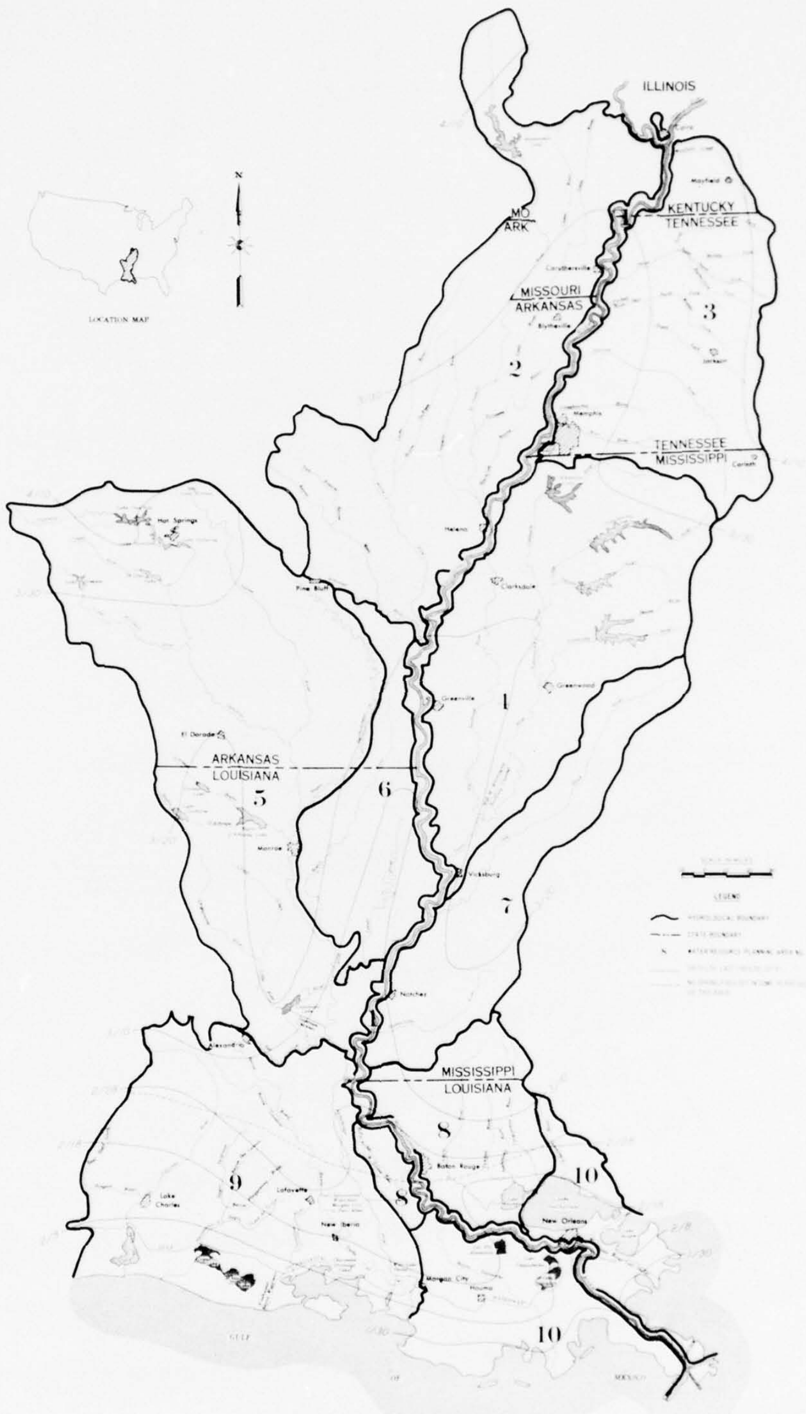


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN DATE OF FIRST FREEZING (32° F) TEMPERATURE IN FALL

1921–1950

FIGURE 24

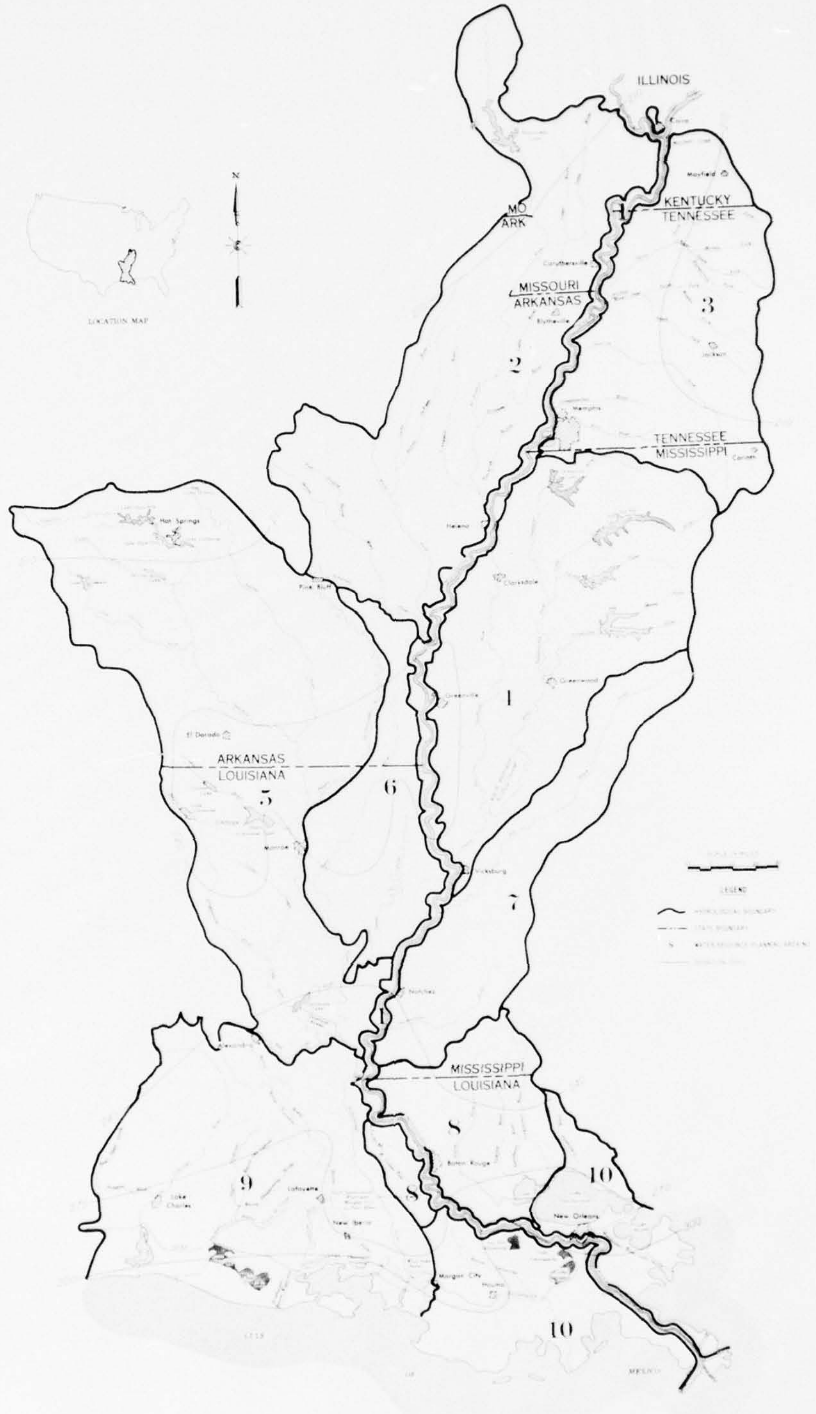


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN DATE OF LAST FREEZING (32° F) TEMPERATURE IN SPRING

1921–1950

FIGURE 25

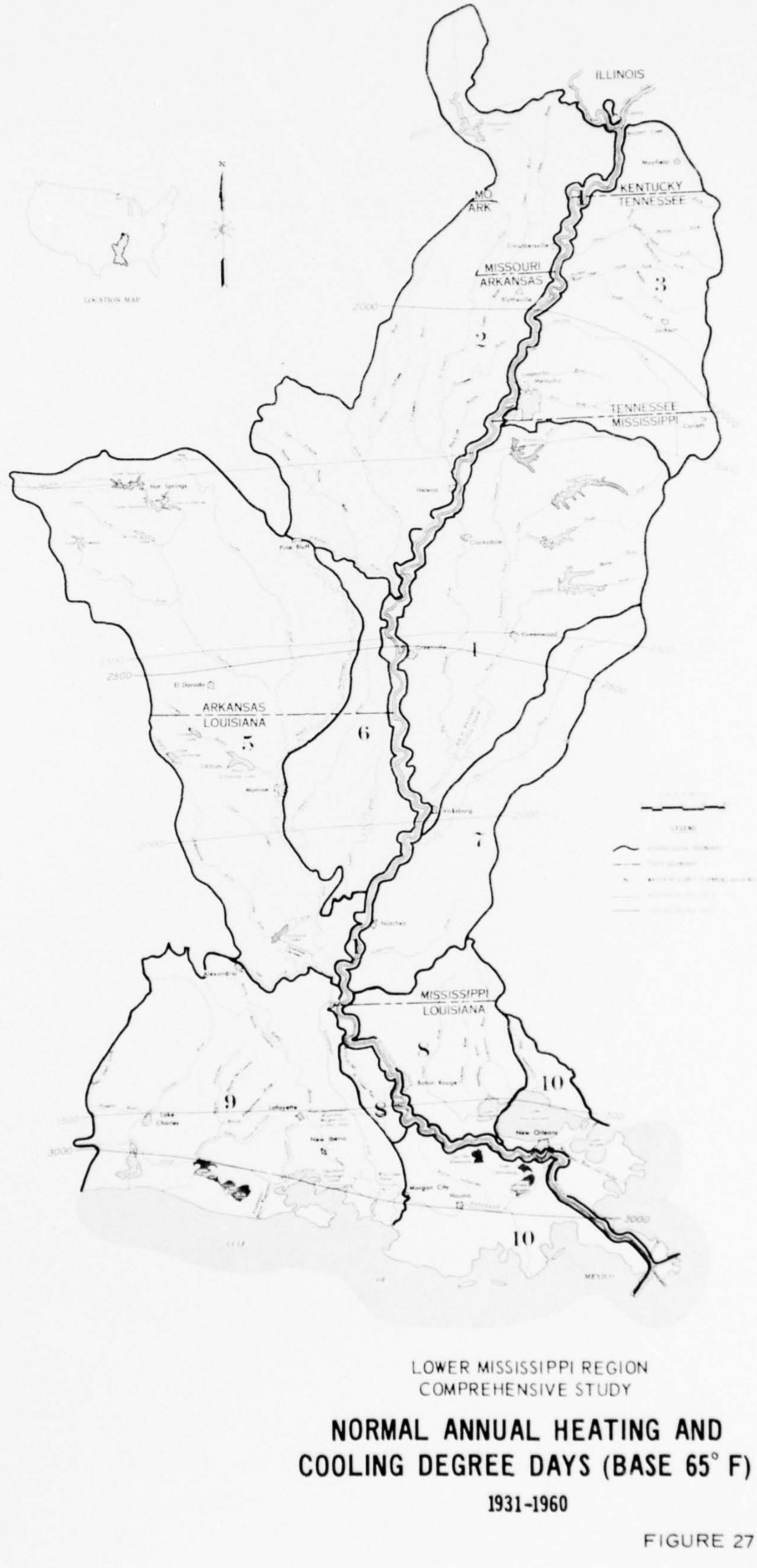


LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN LENGTH OF 32° F FREEZE-FREE PERIOD (DAYS)

1921–1950

FIGURE 26



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

NORMAL ANNUAL HEATING AND COOLING DEGREE DAYS (BASE 65° F)

1931-1960

FIGURE 27

Humidity

Introduction. Humidity is the expression of the water vapor content of air. Humidity is measured and defined in several similar but different ways. The most common expression is relative humidity, defined (52) as the dimensionless ratio of the actual water vapor in the air at a certain temperature to the saturation vapor pressure of air at the same temperature. Relative humidity is usually given as a percentage. The moisture-holding capacity of air is a function of temperature, i.e., relative humidity decreases as temperature increases when the amount of water vapor remains the same.

Another, more conservative, expression of the moisture present in the atmosphere is the dew point, defined (52) as the temperature to which a given parcel of air must be cooled at constant pressure in order for the parcel to reach saturation. With a given moisture content, the dew point would remain constant with temperature changes.

Relative humidity. Table 5 shows the seasonal and diurnal variations of relative humidity at New Orleans, Lake Charles, and Memphis. Data are from the Weather Bureau series, "Summary of Hourly Observations, 1951-1960" (148). The table covers the four midseason months of January, April, July and October, and the approximate times--6 a.m. and 3 p.m.--of the diurnal maximum and minimum of the non-conservative, temperature-sensitive relative humidity.

Dew points. Figure 28, from the Climatic Atlas of the United States (141), shows mean dew point temperatures for January and July and maximum persisting 12-hour, 1000-millibar dew points for the same months. The persisting dew points have been used in hydrologic studies as indices of the maximum precipitable water in the atmosphere.

Relatively large latitudinal gradients of dew point temperature are characteristic in January, but the uniformity of the moisture regime of the region in July is strikingly evident from the almost gradientless pattern.

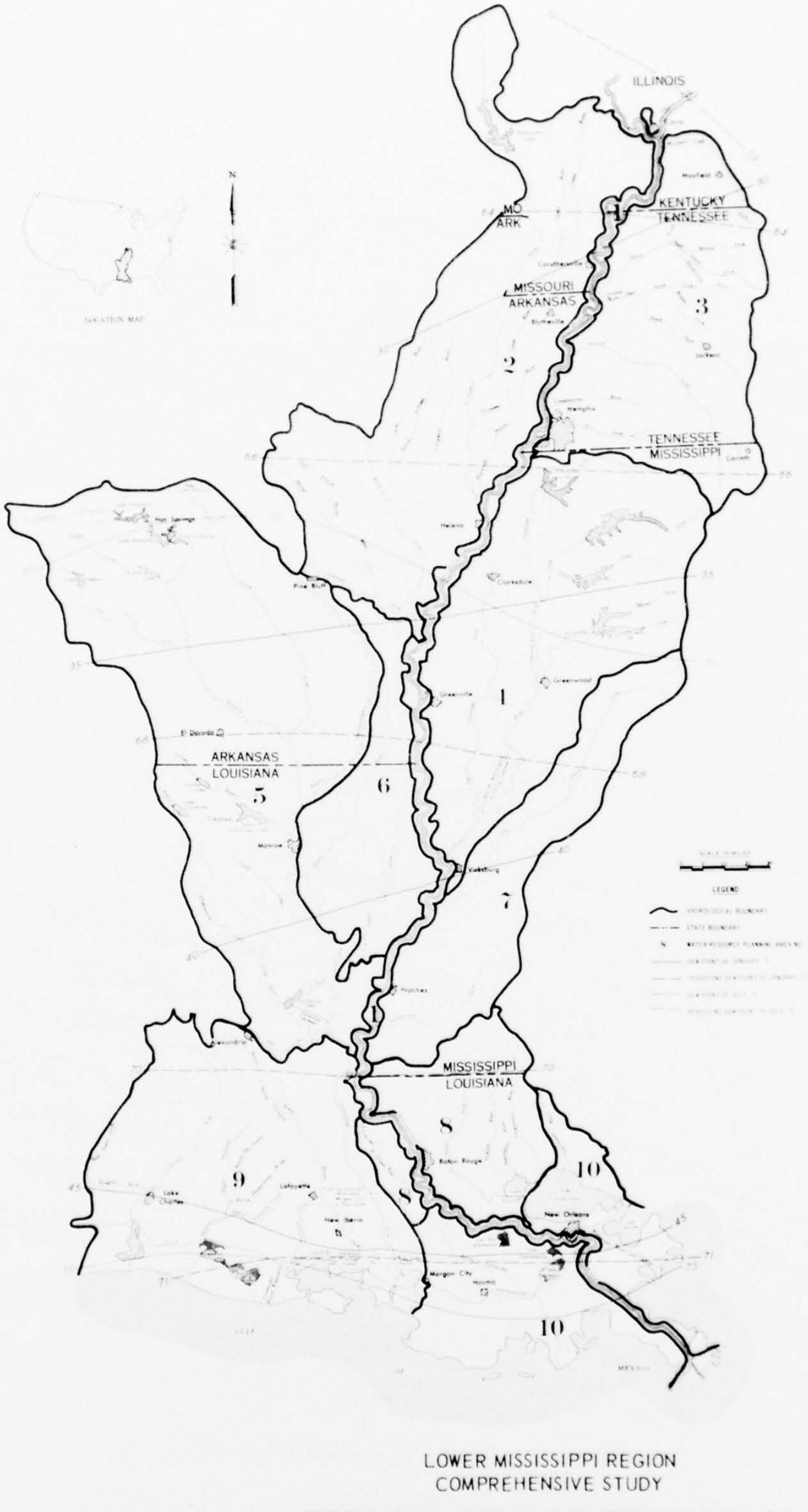
Winds

Seasonal direction and speed patterns. Seasonal wind roses for New Orleans, Lake Charles, and Memphis are shown in figures 29, 30, and 31, respectively. These roses indicate the percentage of time with wind from the various directions (N, NNE, NE, etc.). The data used are observations of wind speed and direction taken once per hour during the years 1951 through 1960, compiled from the Weather Bureau's "Summary of Hourly Observations, 1951-1960" series (148). Seasons are December, January, February - winter; March, April, May - spring, etc. The mean scalar wind speed for each direction and the percentage of the total observations showing calms (speed less than 0.5 mile per hour) are indicated.

Table 5 - Percentage Frequencies of Relative Humidity Observations at 6 a.m. and 3 p.m. During Midseason Months, 1951-1960

	Relative Humidity %	6 a.m.				3 p.m.			
		Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
Memphis	0-29	0	0	0	0	6	18	3	20
	30-49	3	3	0	2	29	43	49	47
	50-69	24	21	4	9	29	24	35	19
	70-79	17	23	21	17	13	7	6	6
	80-89	29	30	40	38	13	4	5	3
	90-100	27	23	35	33	11	4	2	5
New Orleans	0-29	0	0	0	0	4	6	+	6
	30-49	2	2	0	2	25	30	12	33
	50-69	12	9	1	9	42	44	48	41
	70-79	14	7	2	7	12	9	20	9
	80-89	22	22	20	33	9	6	11	5
	90-100	51	59	77	49	8	4	8	5
Lake Charles	0-29	0	0	0	0	6	9	+	12
	30-49	1	+	0	+	25	28	22	41
	50-69	12	6	+	8	27	40	53	34
	70-79	10	6	3	7	19	13	10	7
	80-89	20	22	25	26	13	6	11	4
	90-100	57	65	72	58	9	3	4	2

+ Less than 0.5



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN DEW POINT TEMPERATURE, °F (1946-1965) AND MAXIMUM PERSISTING 12-HOUR 1000 MB DEW POINT, °F

JANUARY AND JULY

FIGURE 28

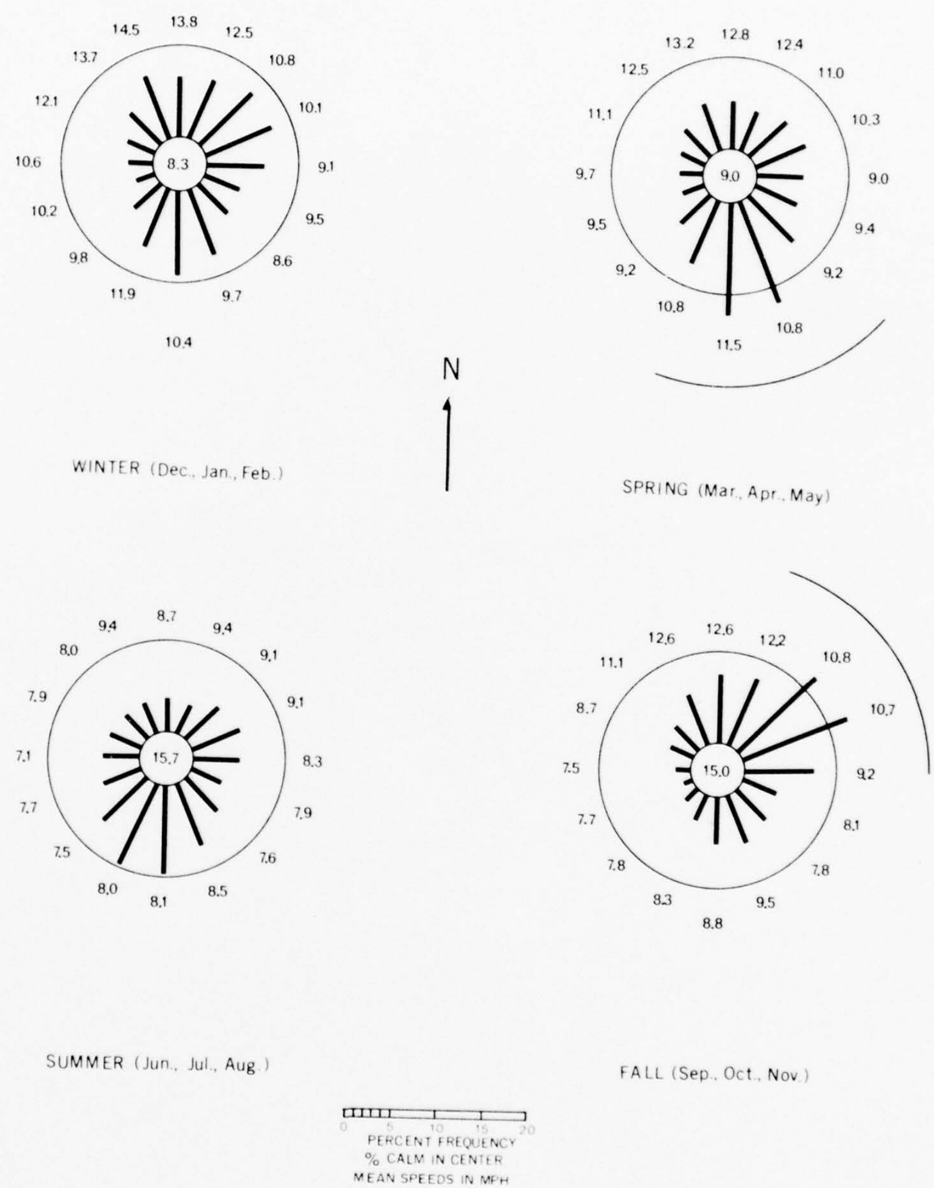


Figure 29. Seasonal Wind Roses, New Orleans, Louisiana, 1951-1960

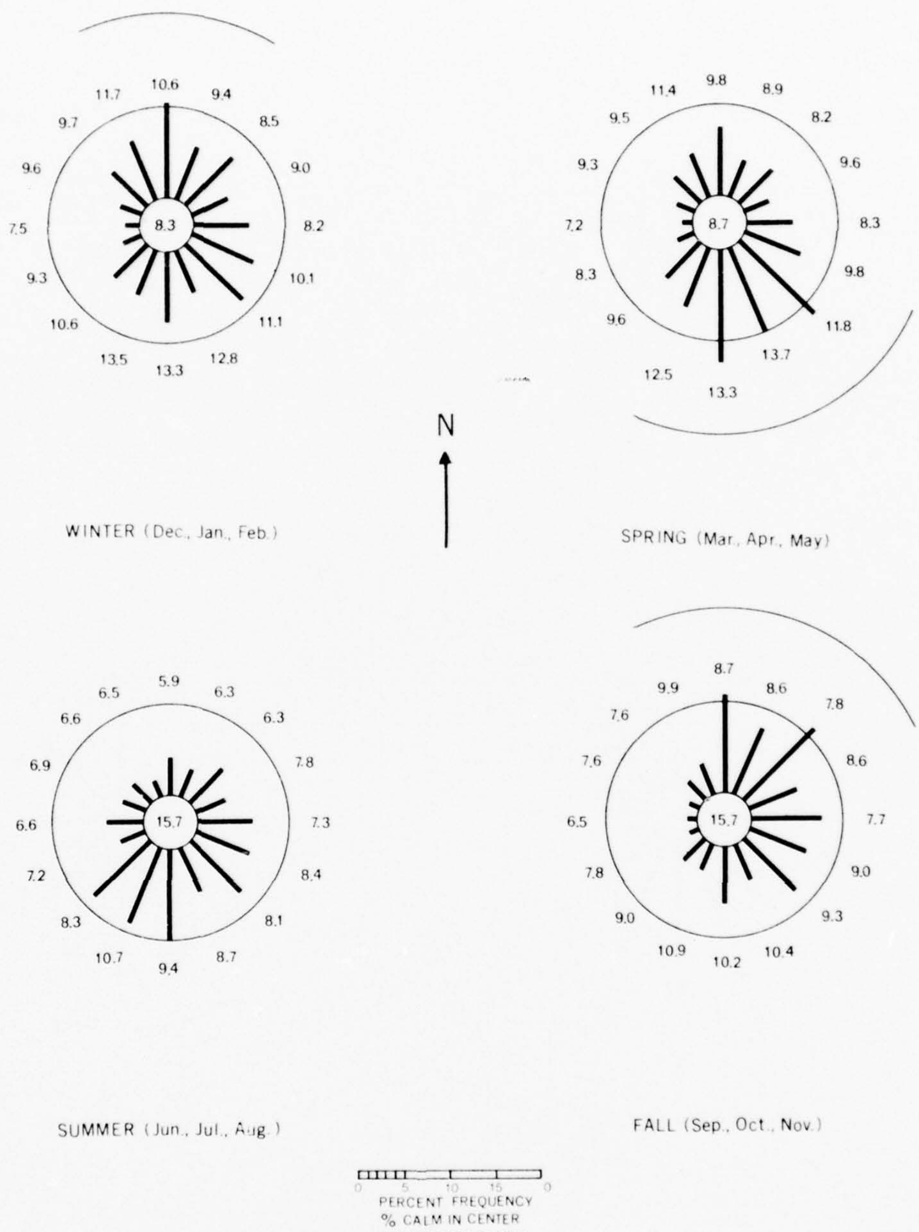


Figure 30. Seasonal Wind Roses, Lake Charles, Louisiana, 1951-1960

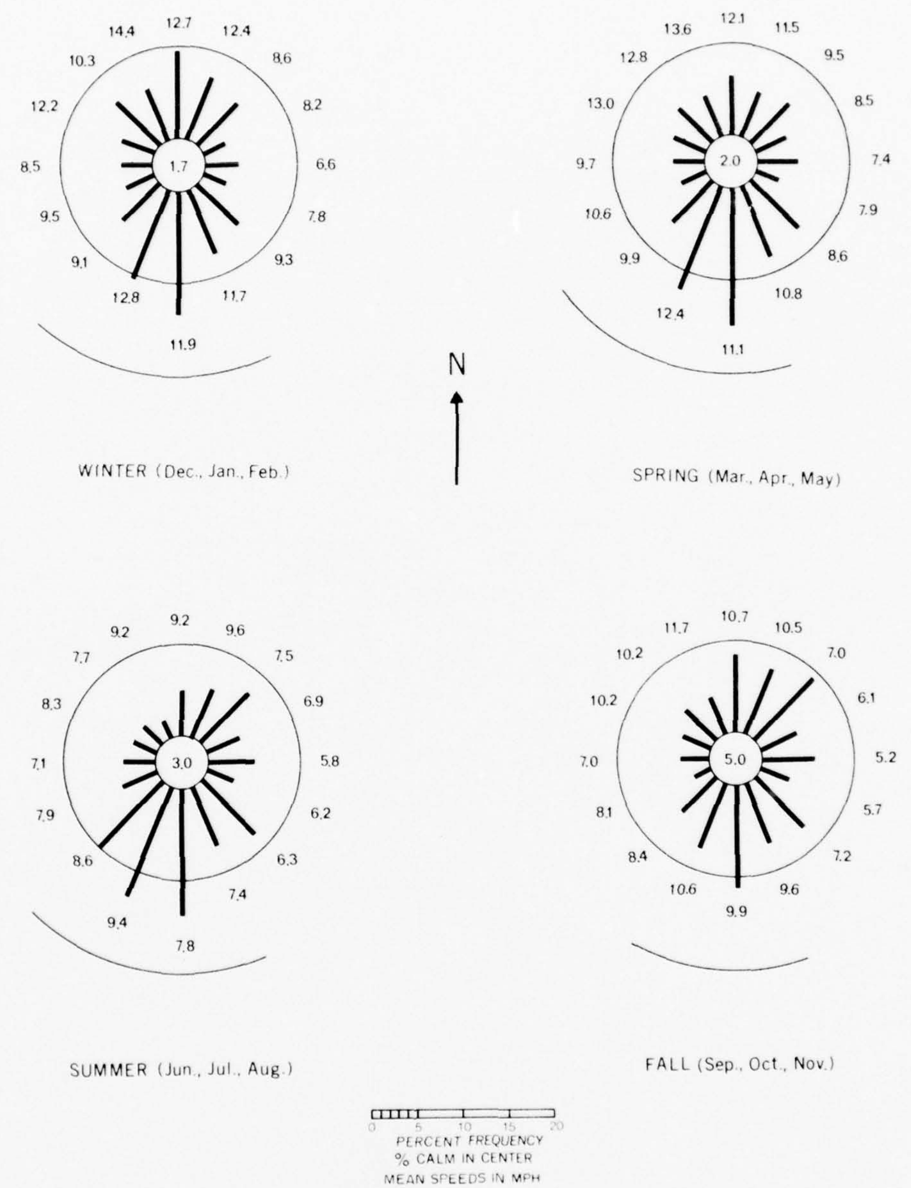


Figure 31. Seasonal Wind Roses, Memphis, Tennessee, 1951-1960

Table 6 gives seasonal percentage frequencies of the hourly wind observations in various speed classes.

Extreme winds. The maximum winds occurring in the lower Mississippi Region have little influence on the long-term wind averages because the extreme winds, often associated with hurricanes, intense middle latitude storms, and squall lines, rarely affect any particular location and because extreme wind speeds are seldom maintained at one place for more than a few minutes to a few hours.

Thom (113) has analyzed the series of annual fastest-mile wind speeds observed at first-order Weather Service stations. Figure 32 shows the standardized extreme one-mile wind expected on a 100-year mean recurrence interval over the Lower Mississippi Region. The more frequent influences of hurricanes in south Louisiana and of intense middle latitude storms in the northern sections combine to produce a latitudinal distribution of extreme winds with maxima in the northern and southern extremities of the region.

Evaporation and Evapotranspiration

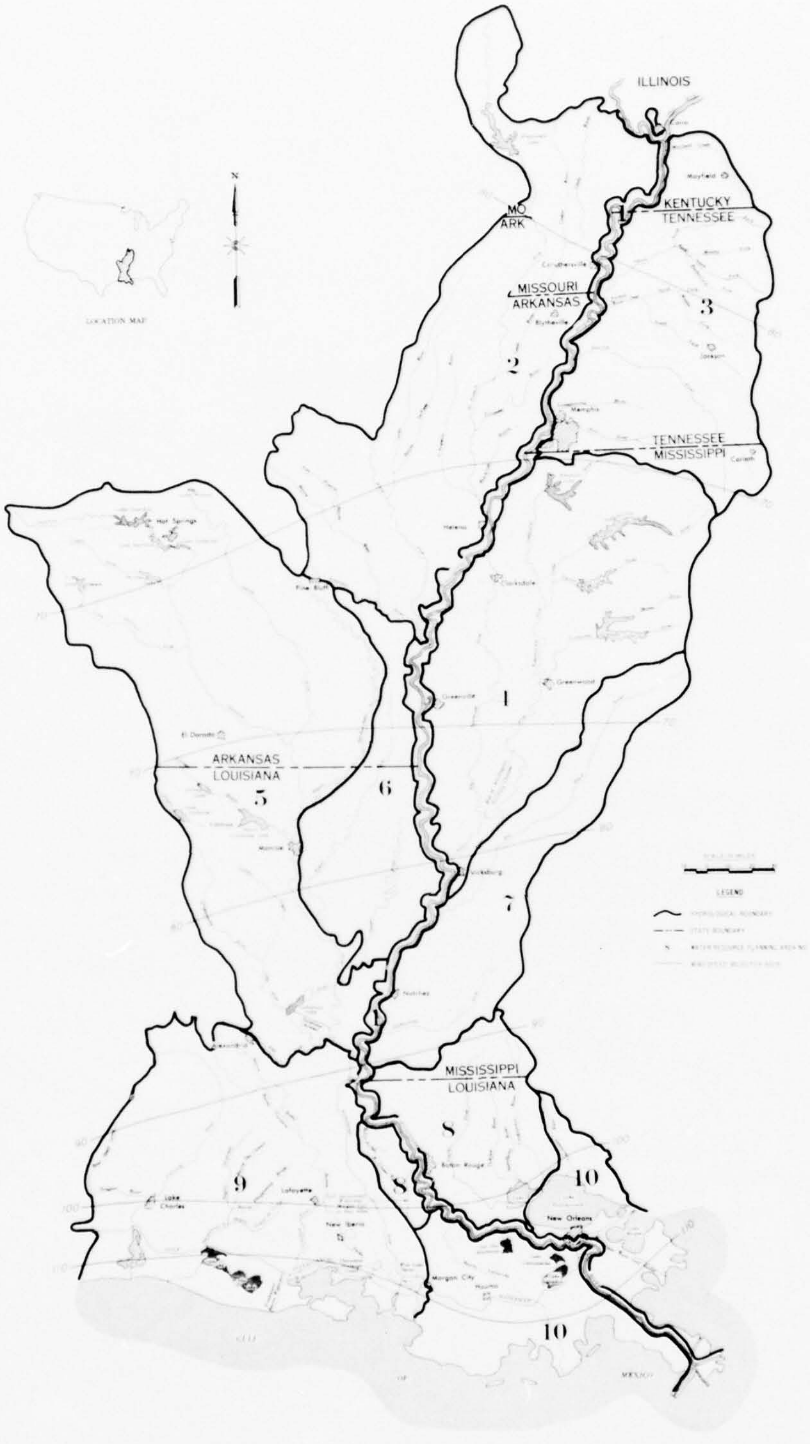
Evaporation. Evaporation is the process by which water is transformed from the liquid state to the gaseous vapor state. The rates of natural evaporation from the oceans, lakes, and other water bodies are strongly affected by temperature, humidity, and wind. Measurements of evaporation are made at a network of selected stations equipped with evaporation pans. The mean annual total pan evaporation, in inches, over the Lower Mississippi Region is shown in figure 33, adapted from Weather Bureau Technical Paper No. 37 (56). Studies have shown that this pan evaporation exceeds natural evaporation of larger water bodies. Coefficients have been developed relating pan to lake evaporation, and range from 0.73 to 0.77 over the area of the region. The mean annual total lake evaporation is indicated in figure 33. The maximum amount, in excess of 50 inches per year, occurs in southwestern Louisiana.

High temperatures have a pronounced effect on the evaporation rate. Figure 33 shows the percentages of the total annual evaporation that occur during the warmer half of the year (May through October). In southern Louisiana, two-thirds of the annual total evaporation occurs during the six warmer months. In extreme northern areas of the region, this amount may range to as high as three-quarters of the total evaporation.

Evapotranspiration. The combination of evaporation from the ground surface and transpiration from plants when the landscape is completely covered with vegetation and when supplies of soil moisture are adequate is called potential evapotranspiration. Thornthwaite, Mather, and Carter (114) give estimates of annual averages of potential evapotranspiration ranging from nearly 30 inches in some northern sections of the region to more than 40 inches throughout most of

Table 6 - Seasonal Percentage Frequencies of Wind Speeds (mph) Within Specified Classes

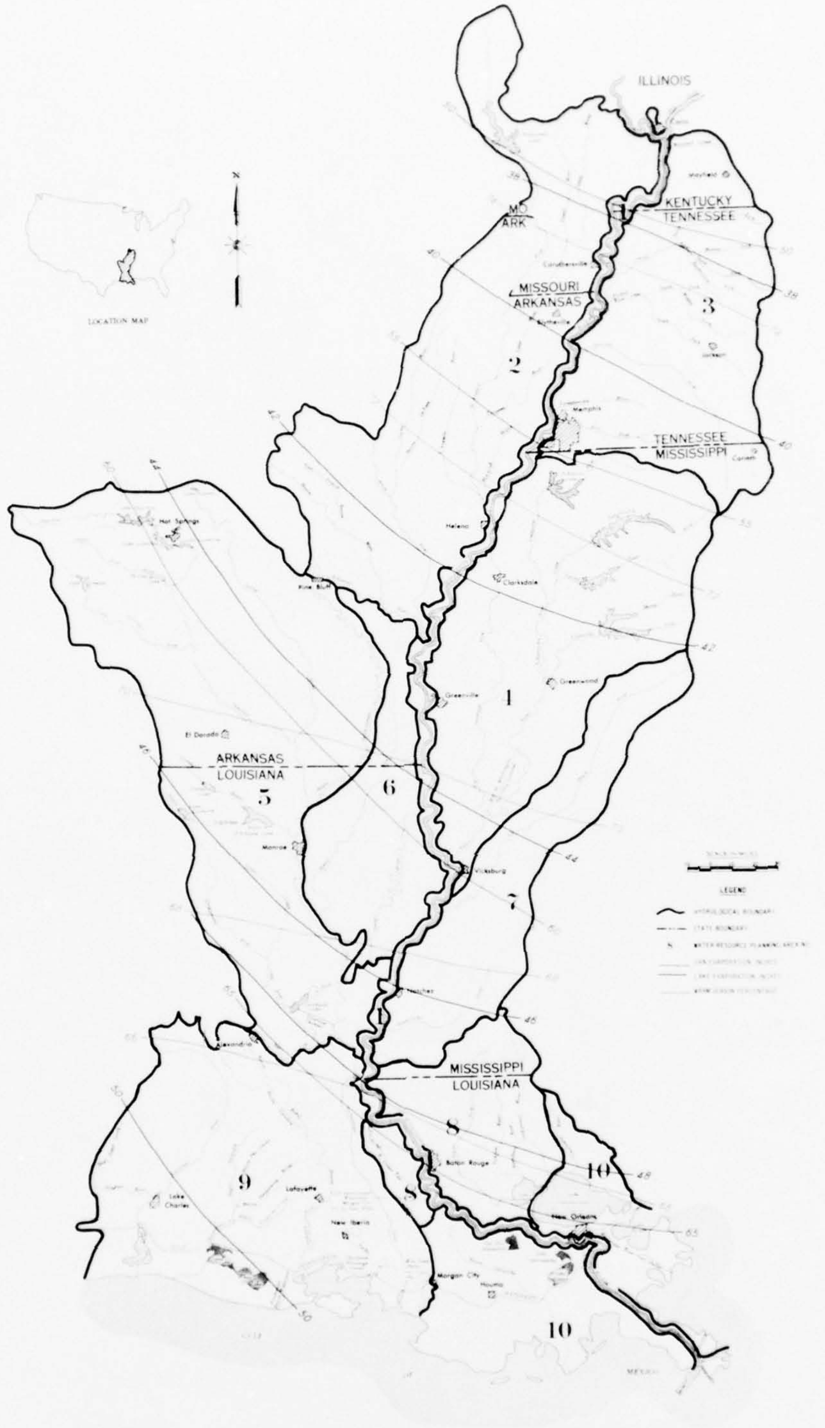
		Speed, mph 0-3	4-12	13-24	>25
New Orleans	winter	11	55	32	2
	spring	11	58	29	2
	summer	21	68	11	0
	autumn	20	55	24	1
		0-3	4-12	13-24	>25
Lake Charles	winter	13	57	27	2
	spring	13	56	29	2
	summer	25	63	12	0
	autumn	22	61	16	1
		0-3	4-12	13-24	>25
Memphis	winter	10	56	33	1
	spring	9	57	33	1
	summer	17	71	12	0
	autumn	20	59	21	0



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

WIND: ANNUAL EXTREME FASTEST MILE (STANDARDIZED 30 FEET ABOVE GROUND), 100 YEAR MEAN RECURRENCE INTERVAL

FIGURE 32



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

EVAPORATION: MEAN ANNUAL CLASS A PAN AND LAKE, INCHES; MEAN WARM-SEASON (MAY-OCTOBER) AS PERCENT OF ANNUAL TOTAL, 1946-1955

FIGURE 33

Louisiana. Actual evapotranspiration over a long period averages only 70 to 90 percent of the potential value, since periods of limited moisture availability occur from time to time.

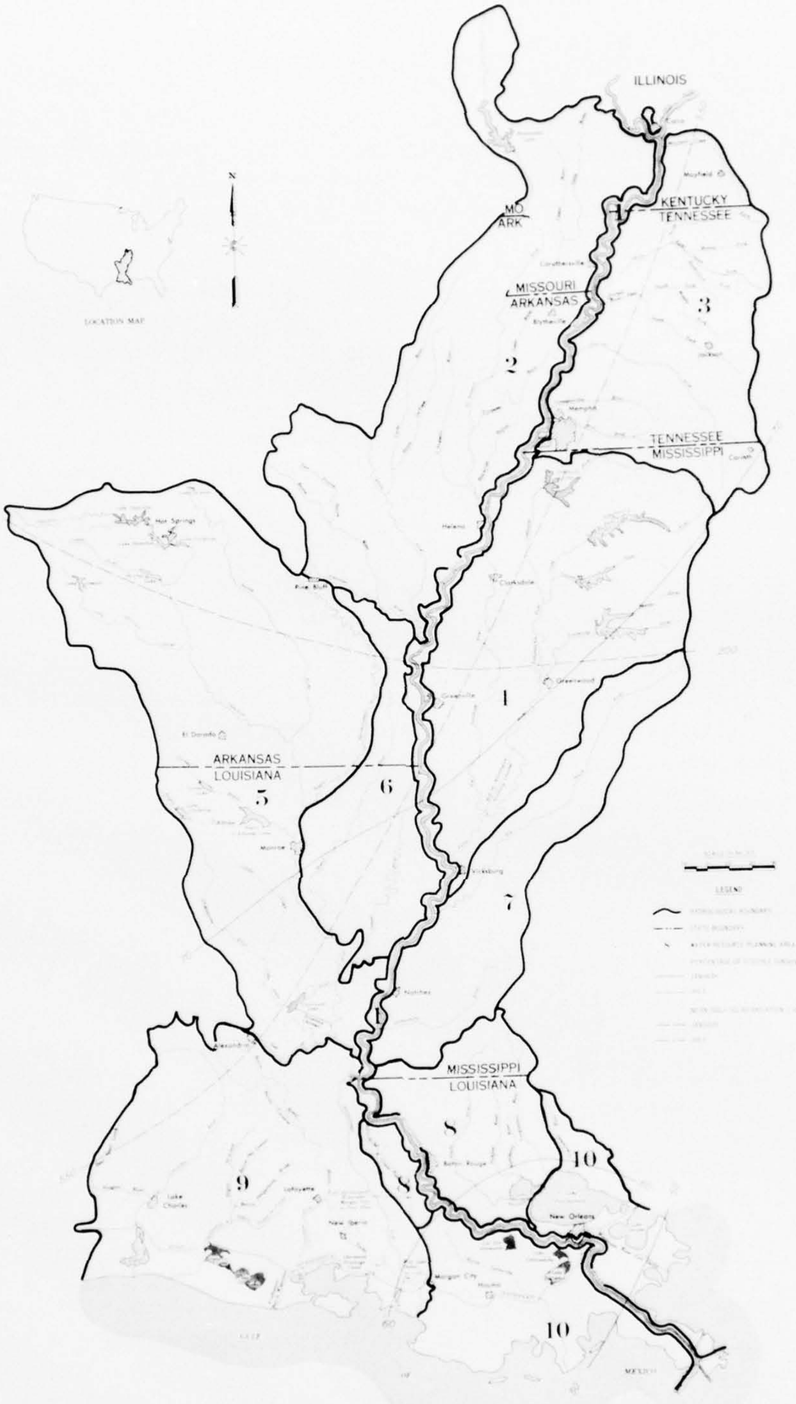
Other Elements

Sunshine and solar radiation. Figure 34, from the Climatic Atlas of the United States (141), shows analyses of percentage of possible sunshine (ratio of duration of actual sunshine to the astronomically possible sunshine) over the Lower Mississippi Region during the months of January and July. In January, the amounts of actual sunshine are less than one-half of the total possible throughout the region with the exception of the "bird's foot" of the Mississippi delta. General and persistent stratoform clouds associated with the passage of low pressure areas and frontal systems reduce sunshine.

In spite of the abundant and frequent precipitation during July over the southern section of the region, the percentages of possible sunshine there are relatively high, and increase northward so that most of the region in Arkansas, Mississippi, Tennessee, Kentucky, and Missouri receives more than 70 percent of total possible sunshine. The nature of the convective processes through which clouds form, precipitate, and dissipate during this warm season precludes skies being cloudy all day.

Figure 34 also shows the mean daily total solar radiation in Langleys (gram-calories per square centimeter) for January and July. The patterns, controlled by solar angle, day length, and daylight cloudiness, are latitudinal in January (increasing from north to south) and longitudinal in July (increasing from east to west (141)).

Clouds and fog. Mean sky cover or average cloudiness is given in the Climatic Atlas of the United States (141). For the region, annual averages range between 50 and 60 percent sky cover. The fallacy of utilizing one such "average" number to represent many climatic distributions is illustrated by table 7. The detailed data shown in table 7, taken from the Weather Bureau's "Summaries of Hourly Observations, 1951-1960"(148), indicate that cloudiness follows a U-shaped frequency distribution, with both clear (0 to 30 percent sky cover) or cloudy (80 to 100 percent sky cover) conditions much more frequent than partly cloudy (40 to 70 percent sky cover) conditions in all seasons. Partly cloudy skies resulting from cumulus clouds during the warmer months are reflected in increased PC values, but clear or cloudy skies are still significantly more frequent. However, when all observations are averaged to obtain a single "average cloudiness," the resultant figure falls in the middle of the least frequent condition.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN PERCENTAGES OF POSSIBLE SUNSHINE AND MEAN DAILY SOLAR RADIATION, LANGLEYS, PERIOD OF RECORD THROUGH 1963 AND 1964

JANUARY AND JULY

FIGURE 34

Table 7 - Monthly Averages of Percentage Frequencies of Cloud Cover, Based on Summaries of Hourly Observations, 1951-1960

Memphis, Tenn.	Tenths Cloud Cover	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clear	0-3	31	33	35	39	41	47	42	53	58	56	48	40
Partly cloudy	4-7	8	10	11	13	18	21	25	21	14	12	11	9
Cloudy	8-10	61	57	54	48	42	32	34	26	28	32	41	52
Little Rock, Ark.													
Clear	0-3	34	36	38	39	39	49	43	54	60	56	50	42
Partly cloudy	4-7	8	9	10	12	17	21	24	21	14	12	10	8
Cloudy	8-10	58	55	52	49	44	31	34	25	26	32	40	50
Shreveport, La.													
Clear	0-3	34	36	38	38	40	54	51	56	59	59	50	42
Partly cloudy	4-7	8	9	10	11	17	18	20	19	13	10	9	8
Cloudy	8-10	57	55	52	50	43	28	29	25	28	31	42	50
Jackson, Miss.													
Clear	0-3	32	34	35	42	43	47	39	51	52	57	46	39
Partly cloudy	4-7	11	11	14	15	21	25	28	23	15	13	12	10
Cloudy	8-10	57	55	50	43	37	28	33	26	32	30	42	51
Lake Charles, La.													
Clear	0-3	33	32	34	36	39	46	38	44	49	57	41	37
Partly cloudy	4-7	11	11	12	14	22	27	27	25	19	14	13	10
Cloudy	8-10	57	57	54	49	38	27	35	31	32	29	46	53
Baton Rouge, La.													
Clear	0-3	35	34	37	40	43	46	38	47	47	58	45	40
Partly cloudy	4-7	12	11	13	14	21	23	24	20	17	12	12	9
Cloudy	8-10	53	55	50	47	36	31	38	33	36	30	43	51
New Orleans, La.													
Clear	0-3	36	35	36	42	49	50	39	47	48	60	47	39
Partly cloudy	4-7	13	14	14	19	21	24	26	23	17	14	12	12
Cloudy	8-10	51	51	50	40	30	26	35	29	35	27	41	50

Fog is a visible aggregate of minute water droplets suspended in the atmosphere near the earth's surface. It differs from clouds only in that the base is at the surface, while clouds are above the surface (52). In the region, the average number of days per year with heavy fog (visibility restricted to 1/4 mile or less) ranges from less than 15 at some interior locations to nearly 50 in some coastal sections of Louisiana. Light fogs are considerably more frequent. Since fog formation through radiational cooling and advection of warm air over cool surfaces involves small-scale micrometeorological processes, considerable variations in frequency within short distances are possible.

Atmospheric pressure. Atmospheric pressure and its variations received considerable attention during the early development of meteorology beginning in the nineteenth century. In recent years, however, the importance of pressure as an indicator of future weather conditions and as a climatic element has declined.

Monthly sea level pressure averages for four stations in the Lower Mississippi Region (158) are shown in table 8. Highest averages are for late autumn and winter; lowest averages are for early summer.

Table 8 - Mean Monthly Sea Level Pressure in Millibars

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New Orleans	20.4	18.6	17.0	16.0	15.4	15.0	16.8	15.4	15.0	17.1	19.9	20.9
Vicksburg	20.6	18.6	16.9	16.3	15.0	14.0	16.5	15.9	15.8	17.9	20.7	20.1
Memphis	20.5	18.8	16.8	15.4	14.9	14.6	15.9	15.7	16.5	18.5	20.3	20.9
Little Rock	20.7	18.7	16.8	15.1	14.6	14.3	15.9	15.2	16.5	18.6	20.2	20.8

1000 mb to be added: 20.4 = 1020.4

Annual average sea level pressure for all four stations listed in table 8 is essentially the same, i.e., 1017.3 or 1017.4 millibars. Extremes of pressure in the region have been associated with tropical cyclones along the coast and with middle latitude storms in the interior areas (minima); and with massive continental anticyclones (maxima). Pressures near 950 mb have been recorded in coastal hurricanes, and pressures near 980 mb have been recorded in interior storms. The range of the maxima, occurring in massive continental anticyclones during winter, is 1044 to 1050 mb.

Climatic Hazards

Tropical Cyclones (Hurricanes)

Introduction. In the two and one-half centuries since Europeans first settled in the Lower Mississippi Valley, scores of hurricanes and tropical storms have swept inland from the Gulf of Mexico to pass over the region. Some have been mild--even beneficial--bringing no more than brief, gusty winds and locally heavy rainfall. Others have been accompanied by violent winds well in excess of 100 miles per hour (30), massive inundations of broad sections of the coastal area reaching 10 to 15 feet above mean gulf level (42), and torrential rainfalls of 10 to more than 20 inches within 24 hours (97), which produced extensive flooding of interior areas.

Within the past decade, two extremely intense hurricanes have caused total damages in the United States of almost $1.5 billion each (145). Both Betsy in September 1965 and Camille in August 1969 struck the central Gulf coast and affected much of the Lower Mississippi Region.

The details of tropical cyclone formation are not yet completely known. These storms are the results of complex interactions in the warm moist tropical atmosphere. In the tropical Atlantic, Caribbean and Gulf of Mexico, vast amounts of water vapor, evaporated from the ocean surface, are converted by convection back to liquid water and, in the process, heat is released. Convective clouds are a daily phenomenon of the tropics; they sometimes develop into thunderstorms, sometimes not. Infrequently, some outside mechanism, such as an easterly wave, an eddy from an active intertropical convergence area, or a polar disturbance intruding into the tropics tends to structure the convection. Once organized, the heat released by small-scale convective clouds can supply energy to larger scales of motion and assist in maintaining a center of low pressure. As the wind begins to circle the low pressure area, friction enhances a spiraling inflow toward the center. Momentum is conserved and the wind blows faster as it nears the center. Increased convergence at low levels maintains convection by supplying moisture and vertical motion at the center; the clouds in turn produce more heat, thereby lowering the pressure and increasing the winds, which again increases friction and inflow.

This situation will not persist, however, unless another mechanism at high levels in the atmosphere is present to remove air which accumulates through convergence at low levels. The interaction of low-level and high-altitude wind systems determines the intensity that a tropical cyclone will attain. If less air diverges aloft than converges at the surface, the incipient storm will "fill up" or dissipate. If more air is pumped out than flows in, the central pressure will decrease and the storm will intensify.

Thus, the tropical cyclone can be viewed as a simple heat engine. Fuel is water vapor, evaporated from the ocean surface. Combustion occurs in the towering convective cumulonimbus clouds as latent heat is released when water vapor condenses. An exhaust system is provided by an upper level wind circulation which removes air from the top of the storm. The starter is some "outside influence" which acts to organize the convection.

As with any engine, the storm will falter and stop when any of the necessary components fail. The tropical cyclone decays as it moves inland or recurves northward over colder water and its supply of water vapor "fuel" is reduced. Occasionally tropical cyclones moving into higher latitudes may modify into nontropical storms.

The hurricane is not a very good engine--the efficiency with which it converts thermal to mechanical energy is only about 3 percent. However, the condensation heat energy released by a mature hurricane in one day is often sufficient--if it were converted to electrical energy--to supply the power requirements of the United States for more than 6 months.

Figure 35 (139) shows a mature tropical cyclone in schematic, as it appears on radar and in satellite photographs. The calm eye and the spiral rainbands are unique features of the tropical cyclone.

Eye diameters average about 15 miles, with a range from less than 5 miles to more than 50 miles. This center is surrounded by a region of very intense convection (the eye wall) where the strongest winds are concentrated.

Dunn and Miller (30) describe four stages of tropical cyclone development:

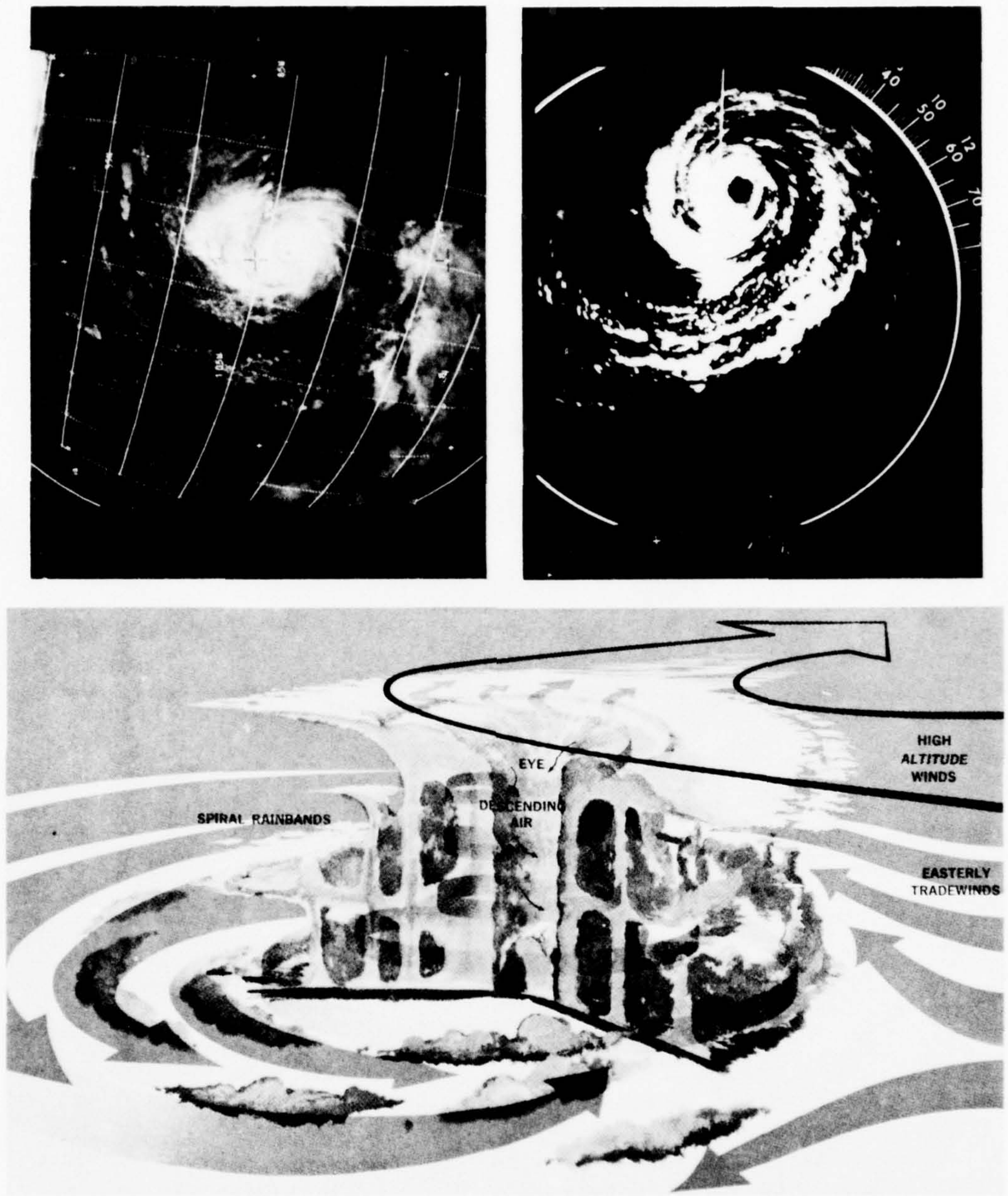
1. Tropical disturbance: circulation slight or absent at surface, sometimes better developed aloft, no closed isobars (lines of equal atmosphere pressure), no strong winds.

2. Tropical depression: one or more closed isobars and some rotary circulation at surface, maximum wind speed less than 39 miles per hour (34 knots).

3. Tropical storm: closed isobars; distinct rotary circulation, maximum wind speed 39 to 73 miles per hour (34 to 63 knots).

4. Hurricane: closed isobars, pronounced rotary circulation, wind speed 74 miles per hour (64 knots) or higher.

Less than half the tropical circulations reaching storm intensity in the Atlantic region ever attain hurricane intensity.



(Courtesy of National Oceanic and Atmospheric Administration)

Figure 35. Portrait of a Hurricane, as Seen by Satellite, Radar, and Illustrator

Frequencies. Figure 36 (top), adapted from "Atlantic Hurricane Frequencies along the United States Coastline" (100), shows total numbers of tropical cyclone coastal crossings during the period 1886 through 1970 in 50-mile segments along the Gulf Coast, outlined in the bottom section of the figure. The assumption has been made that hurricane-force storms crossing the coastline in one of the segments also affected the segment toward the right (east) of the path.

Great hurricanes are defined as those cyclones with sustained winds 125 miles per hour or higher. Simpson and Lawrence (100) noted that:

> "(this) maximum wind threshold carries with it the likelihood of severe structural damage to residences and small industrial plants where building codes specifically designed to protect against a mature hurricane have not been enforced. The central pressure of approximately 950 millibars, which normally accompanies this wind value, can be associated with storm surge heights as high as 12 to 15 feet...."

Figure 36 (center), adapted from Weather Bureau Technical Paper No. 55 (20), shows the year-by-year number of tropical cyclones passing over portions of the Lower Mississippi Region during the 20th Century. Table 9, prepared from data in reference 20, plus recent information from Climatological Data, National Summary (145) shows a frequency summary by month of tropical cyclones which have affected the Lower Mississippi Region.

Table 9 - Total Number of Tropical Cyclones Affecting Portions of the Lower Mississippi Region, 1901-1970

May	Jun	Jul	Aug	Sep	Oct	Nov
1	11	10	16	35	11	1

Hope and Neumann (47) have recently presented detailed information on the seasonal distributions, speed and direction of movement, and prior and subsequent locations of tropical cyclones passing through 2-1/2° latitude/longitude areas of the North Atlantic region. Table 10 summarizes some of their results pertinent to the coastal sections of the Lower Mississippi Region.

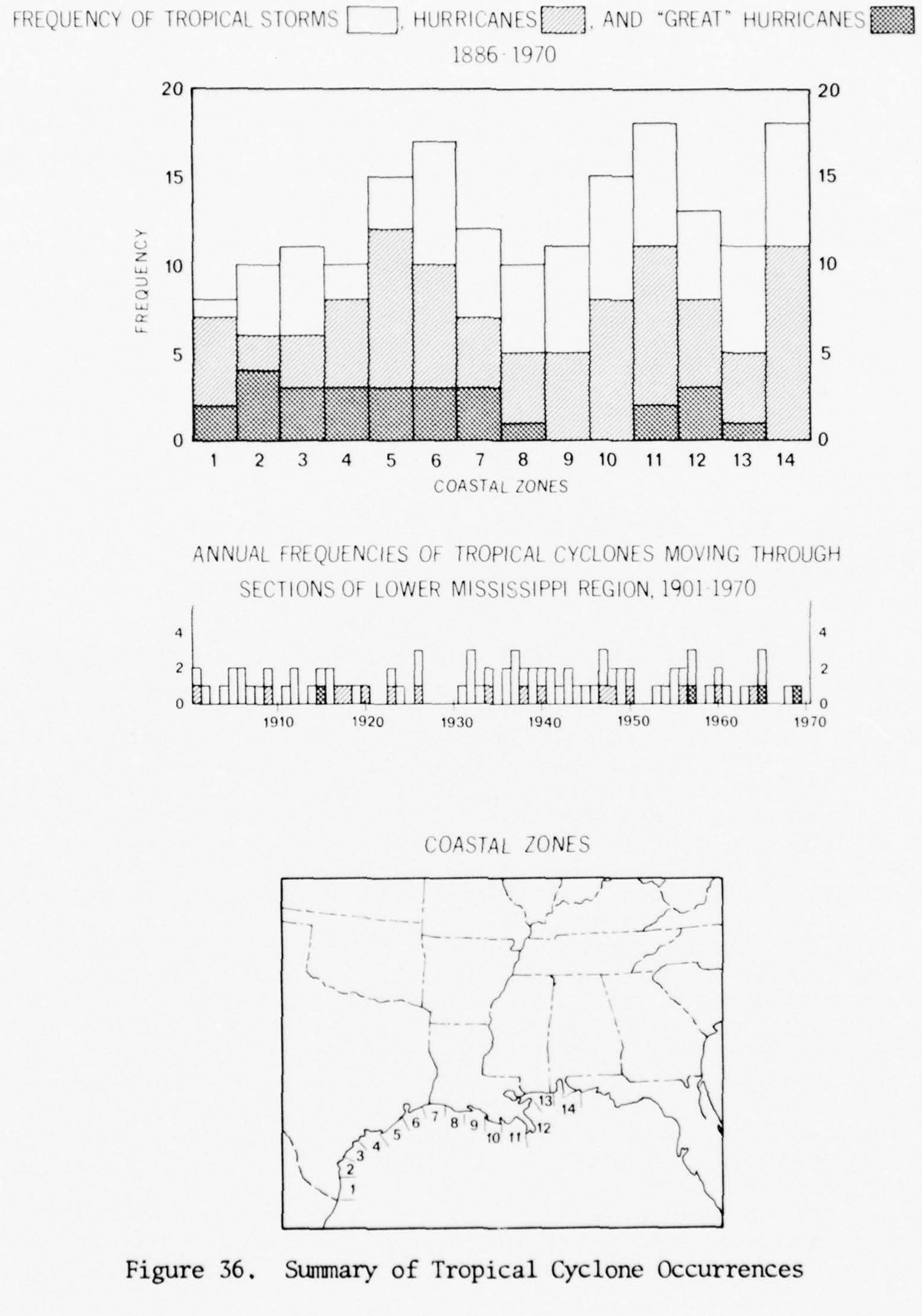


Figure 36. Summary of Tropical Cyclone Occurrences

Table 10 - Tropical Cyclone Frequencies in the Northern Gulf of Mexico, 1886-1969

Area	Total No.	Number Entering Area As: Hurricane	Tropical Storm	Tropical Depression	Poisson Probability of at Least One Storm in any Year
27.5°N-30°N 95°W-97.5°W	36	15	15	6	0.30
27.5°N-30°N 92.5°W-95°W	42	15	22	5	0.36
27.5°N-30°N 90°W-92.5°W	54	18	32	4	0.45
27.5°N-30°N 87.5°W-90°W	55	19	32	4	0.46
27.5°N-30°N 85°W-87.5°W	58	22	29	7	0.46

Cry and Haggard (22) and Alaka (1) show that during the early part of the hurricane season (June), the Gulf of Mexico is a preferred region of storm development. During July and August, formation most often occurs in the Atlantic, east of the Lesser Antilles. However, the August storms often move on paths which bring them into the Gulf of Mexico. September is the peak of hurricane activity. A majority of the month's tropical cyclones form in the Atlantic, but a substantial number have developed in the Gulf of Mexico. Storm development in October tends to be concentrated in the western Caribbean area. Figure 37 (20, 145) displays the paths of several recent significant tropical cyclones.

Tropical cyclone rainfall. The rainfall associated with tropical cyclones normally is quite intense, and storm totals may sometimes reach torrential proportions (table 11). Considerable variability in amounts over relatively short distances is also usual. The amount of rain associated with a tropical cyclone is dependent on several factors (30). The most important factors are the rate of progression of the storm system, the nature of the topography or surface over which it moves, and the source and trajectory of the inflowing air at low levels. The inflow pattern plays a major role in dissipation of storms over land. Surface roughness or friction is greater over land so winds tend to be retarded and blow more directly toward the center of the storm. This increases low-level convergence and the rate of rainfall. However, the increased convergence and the removal of the storm's moisture source are

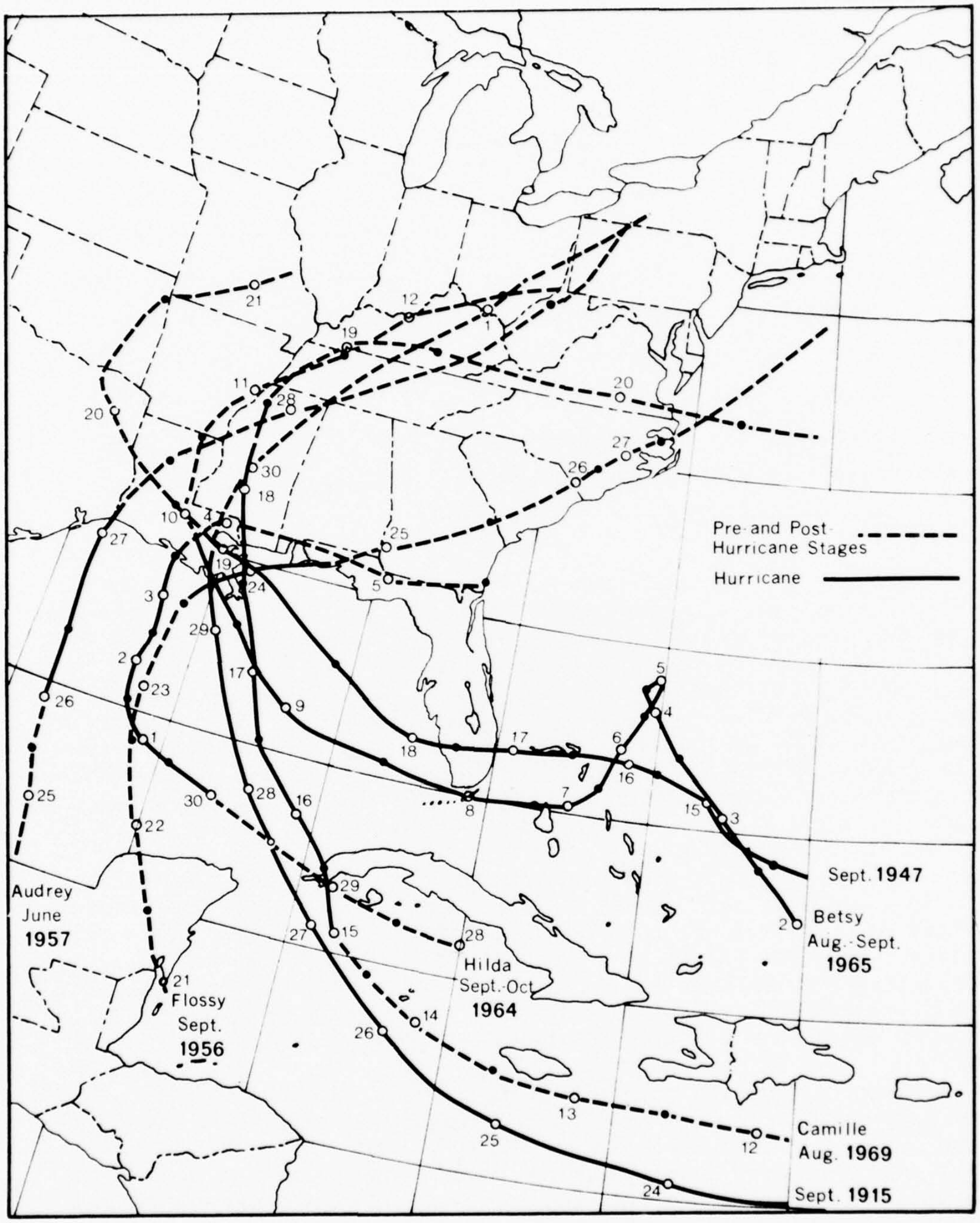


Figure 37. Some Significant Hurricanes Making Landfall in the Lower Mississippi Region

the beginning of dissipation, and the increased rainfall rate is temporary, unless outside, nontropical influences enter to enhance it.

Table 11 - Some Heavy Rainfall Totals in Connection with Tropical Cyclones Affecting the Lower Mississippi Region

33.71 inches	Crowley, La.	August 6-10, 1940 (5 days)
29.65 inches	Lafayette, La.	August 6-10, 1940 (5 days)
21.30 inches	Logansport, La.	July 22-25, 1933 (3 days)
21.40 inches	Alexandria, La.	June 15-16, 1886 (1 day)
19.76 inches	Crowley, La.	August 8-9, 1940 (1 day)
12.44 inches	Shreveport, La.	July 24, 1933 (1 day)

Figure 38 illustrates that the intensity (i.e., the wind speed) of the tropical cyclone circulation and the amounts of rainfall produced are not closely related. Betsy was a large and intense storm (a great hurricane), but the precipitation pattern was relatively light. Camille was also a great hurricane but the size of the circulation was extremely small. The resulting rainfall from Camille was much heavier than in Betsy, but fell over a smaller area mostly very near and to the east of the track. The tropical cyclone of August 1940 was barely of hurricane intensity as it moved inland, and the area of hurricane winds was only about 20 miles wide. A slow movement of the center westward just off the Louisiana coastline, with almost half of the circulation over land, produced more than 30 inches of rain in 5 days at a few points in south Louisiana, with almost 20 inches in a single day. The tropical storm of July 1933 was never of hurricane force, entered the central Texas coast, and had no strong surface circulation remaining in the regions where the heaviest rainfall occurred. Schoner and Molansky (97) present similar analyses for numerous hurricanes and tropical storms which have affected the Lower Mississippi Region.

Tropical cyclone rainfall results from intense convection and is usually intermittent. Rainfall is concentrated within the eye wall and in the convective element in the spiraling band of inflow, which may extend outward several hundred miles from the eye. Figure 39-A, adapted from Gentry, Fujita, and Sheets (35), shows Hurricane Gladys (1968) photographed from Apollo 7. The photographed cloud patterns have been schematized and radar precipitation echoes superimposed in figure 39-B. The areas between spiral bands often appear cloud-covered in satellite photographs, but radar shows these to be free of heavy precipitation.

Figure 38. Some Examples of Tropical Cyclone Precipitation Patterns in the Lower Mississippi Region

Figure 39-A. Apollo 7 View of Hurricane Gladys at 1531 G.M.T., 17 October 1968

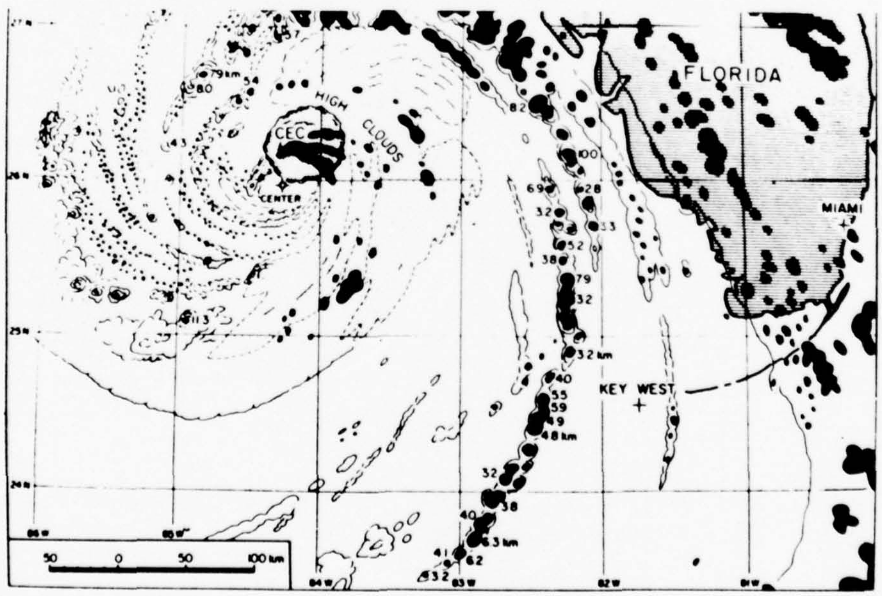


Figure 39-B. Example of Plan Position Indicator Radar Composite Echoes Superimposed upon Cloud Pattern Derived from Apollo 7 Pictures

Beneficial aspects of tropical cyclones. Rainfall from some tropical cyclones has been beneficial in breaking extended periods of drought (110). Numerous other cyclones have ameliorated short-term moisture deficiencies. The potential economic value of this rainfall is great. Benefits must be measured against offsetting destruction, but they usually extend over a much broader region.

Figure 40-A shows tracks of several drought-ending tropical cyclones, and the effects of Cindy (1963) are shown in detail in Figure 40-B. The substantial rainfall over southwestern Louisiana returned moisture conditions to nearly normal from extreme drought (as measured by the Palmer Index).

The overall climatic effects of tropical cyclone rainfall are far-reaching. Cry (21) has shown that tropical cyclones contribute significant amounts to the total precipitation in the southern and eastern United States. Figure 41 shows tropical cyclone rainfall as a percentage of monthly total rainfall. The area is expanded for September to show that tropical cyclones contribute up to 45 percent of the normal monthly rainfall as far north as New Jersey. Percentages for the Lower Mississippi Region range from about 5 to 12 for June-July; from 5 to 25 in August; from 5 to more than 30 in September; and from 5 to more than 20 in October. Details of monthly data for a northern and a southern location in the region are shown in figure 42.

With the possibility of man's future capability of hurricane modification and control directed toward the reduction of severe wind and storm surge damage (34, 51), Sargent (94) has posed an intriguing series of questions relative to tropical cyclone rainfall:

> "If tropical storms were dissipated, mitigated, or diverted, from whence would this moisture come?"
>
> "Does the risk of a water shortage on the East Coast outweigh the biological damage and the socio-economic losses from storm and flood?"
>
> "If the hurricane's course could be directed by a given amount in a given direction, who would make the decision to change the course so that instead of striking Florida (Louisiana), it would be diverted toward Georgia or the Carolinas (Mexico)?"
>
> "On what basis would the decision be made?"

Deficient Precipitation

Introduction. In any area of the world with copious rainfall, such as the Lower Mississippi Region, drought is not often considered to be a significant climatic factor. Drought is a relative condition, however, and rainfall that would be abundant for one region may result in disaster in another. The variability of precipitation on all time

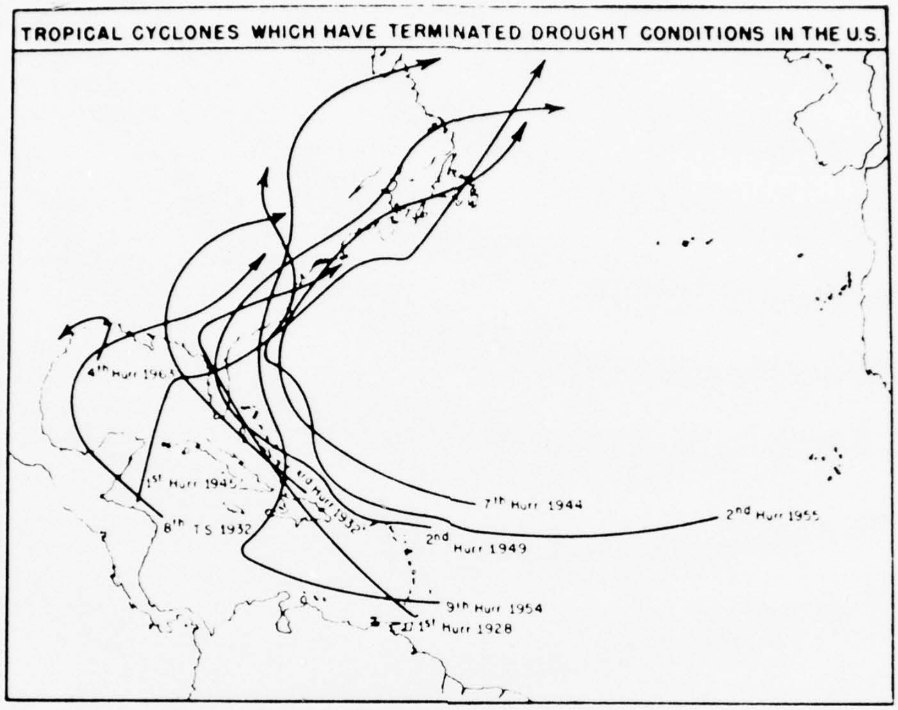
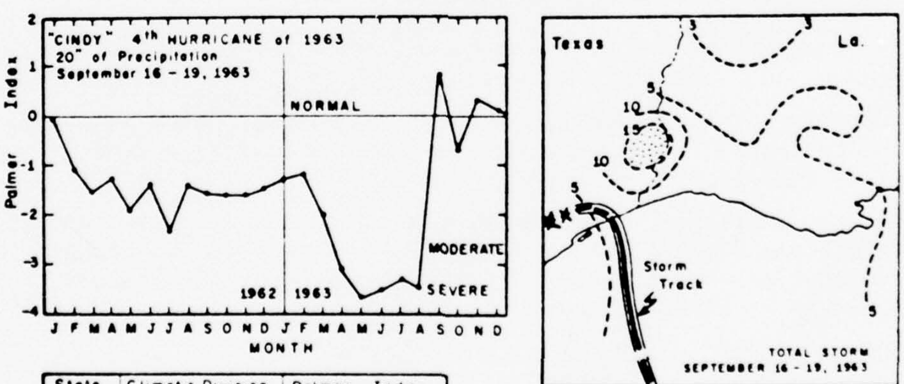


Figure 40-A. Tropical Cyclones Which Have Terminated Drought in the United States



State	Climatic Division	Palmer Index
*La	Southwest	-3.45 to .78

Area of Drought — Approximately 10,000 sq miles
Casualties, 3
Damages, $12,500,000

Figure 40-B. Details of Hurricane Cindy, September 1963

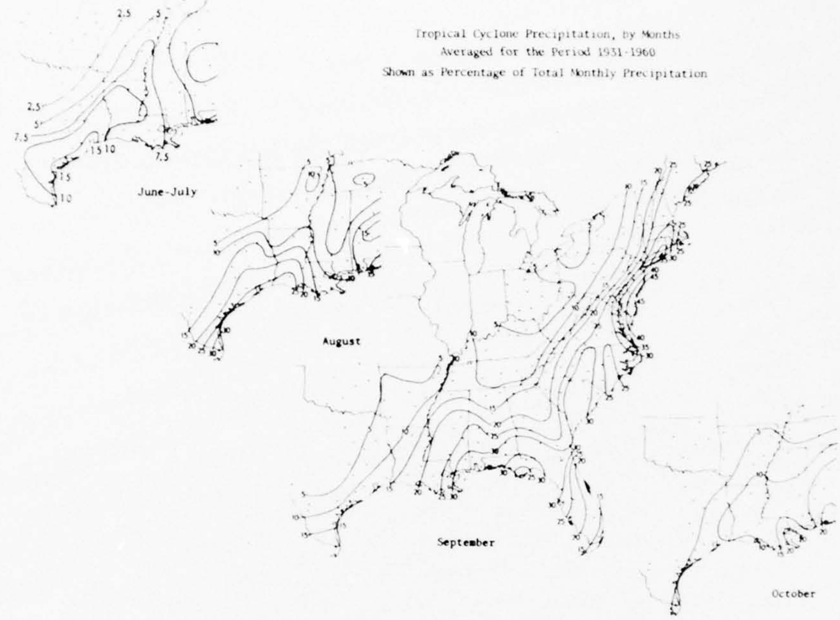


Figure 41. Tropical Cyclone Precipitation, by Months Average for the Period 1931-1960, Shown as Percentage of Total Monthly Precipitation

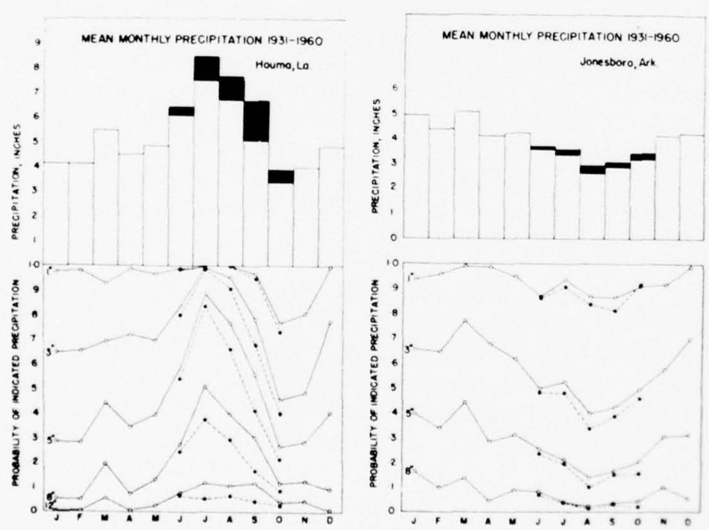


Figure 42. Mean Monthly Precipitation 1931-1960 for Houma, Louisiana, and Jonesboro, Arkansas, with Tropical Cyclone Precipitation Indicated by Shading (Top). Changes in Probabilities of Receipt of Various Threshold Amounts when Tropical Cyclone Precipitation Removed from Monthly Distribution (Bottom)

scales is relatively large--extended periods of drier and of wetter weather occur from time to time in all areas.

Further complicating an objective assessment of drought is a basic definition of the problem: the meaning and perception of drought is dependent on the point of view--agricultural, hydrologic, economic, etc. (78,165).

If the meteorological aspect is regarded as basic--and other aspects as effects--a single generalized definition may be formulated that will allow study and evaluation of frequency, duration, and severity of drought. This should be accomplished through a quantitative parameter capable of evaluating the various meteorological phenomena characterizing prolonged and abnormal moisture deficiencies. Comparison of these index values with effects provides a basis for classification of drought by severity. Such an index has recently been developed (78). The Palmer Index is universal in that persistently normal temperature and precipitation produce an index of zero in all seasons in all climates. Further, the extended period of greatest abnormal dryness of long record produces an index around -6, regardless of the degree of aridity or wetness of the climatic averages of the region being studied.

Palmer index. Meteorological drought is defined as a prolonged and abnormal moisture deficiency. How long is "prolonged?" Usually several months. What is "abnormal?" Abnormality implies deviation from some established norm or average. "Deficiency" indicates a demand which exceeds the available supply. Consequently, a drought period is an interval of time, generally on the order of months or even years in duration, during which the actual moisture supply at a given place consistently falls short of the climatically expected or suitable supply. The severity of drought depends on both the duration and the magnitude of the moisture deficiency.

The Palmer index was designed to allow spatial comparisons as well as temporal evaluations. The index is based on the concept that the amount of precipitation required for the nearly normal functioning of the established regional economy depends on the long-term climate and on the prevalent meteorological conditions both during and preceding the period of interest. The characteristics of recent and past weather are both taken into account. From time to time, droughts of similar severity occur in two regions which have very dissimilar climates--the Lower Mississippi Region as opposed to eastern Oregon, for instance. In effect, the climates in both areas will have been temporarily more arid than usual. Each area, in its own way, becomes disrupted by the unusual dryness. For example, extreme drought in the Lower Mississippi Region might well lead to reports of low water tables, deficient streamflow, depleted reservoirs, and serious shortages of soil moisture. On the other hand, extreme drought in eastern Oregon would

produce complaints of dry ranges, critical fire danger, and a shortage of water for irrigation and livestock. Thus, the many and varied effects of a prolonged period of abnormally dry weather depend on the climatic averages and the established activities in the affected areas.

Palmer's method requires a climatological analysis of a long record in order to derive five constants which define certain moisture characteristics of the climate of the area of interest. Therefore, the first thing required is a month-by-month water balance accounting for a long record, such as 30 years or more. Palmer used a two-layer soil model and the Thornthwaite method of computing potential evapotranspiration; however, other methods could be substituted. Potential values were also derived for runoff, moisture recharge, and moisture loss. Next, the results of the water balance accounting must be summarized to produce the five constants for each of the 12 calendar months. One constant, alpha, is the coefficient of evapotranspiration, the ratio of the computed mean monthly evapotranspiration (ET) to the mean monthly potential evapotranspiration (PE). This ratio is nearly 1.0 in humid climates, but approaches 0 in very arid regions. Another constant, beta, the coefficient of recharge, is the ratio of the mean monthly moisture gain (R) to the mean maximum possible gain (PR). The coefficient of loss, delta, is the ratio of mean moisture loss (L) to mean potential loss (PL), where potential loss is the amount of evapotranspiration that would have occurred if no precipitation had fallen during the month. The coefficient of runoff, gamma, is the ratio of computed mean runoff (RO) to mean potential runoff (PRO).1/ An additional constant, K, is an empirically derived weighting factor which depends on a number of measures of the moisture supply and demand characteristics of the climate in question.

Having developed these coefficients, it is possible to compute the amount of precipitation (P) that should have occurred during a particular month to sustain the evapotranspiration, runoff, and moisture storage that could be considered as "normal" and appropriate for the climate, having taken account of antecedent moisture conditions. The equation is

$$P = \alpha PE + \beta PR + \gamma PRO - \delta PL, \qquad \text{(Eq. 1)}$$

where the potential values are those that apply to the particular period in question.

The computed precipitation is, in fact, an adjusted normal precipitation, the adjustment being dependent on the antecedent weather as reflected by the computed moisture storage and on the anomaly of the

---

1/ Palmer used PRO = Available Water Capacity – PR, but indicated that PRO could be defined as $3\bar{P} - PR$, where $\bar{P}$ = normal monthly precipitation.

potential evapotranspiration during the month in question. Over the long term, the mean of the computed precipitation is equal to the mean of the actual precipitation. However, for a particular month the actual precipitation minus the computed precipitation provides a measure, d, of the degree to which the month was abnormally wet or abnormally dry. When multiplied by the weighting factor K, the moisture anomaly index

$$Z = Kd, \qquad \text{(Eq. 2)}$$

provides a measure which is comparable in space and time.

Inasmuch as a succession of months, most of which were abnormally dry, produces a drought of gradually increasing severity, the final drought index (X) depends on the sequence of Z values. These can be combined by the empirical equation

$$X_c = 0.897\ X_p + Z_c/3.0, \qquad \text{(Eq. 3)}$$

where the subscript c refers to the current month in question and p refers to the previous month.

Results of the analysis of a long record provide a series of monthly drought index values which, in general, range from around 6 to -6. The positive values are more or less incidental to Palmer's basic purpose, but, importantly, they do provide realistic measures of the degree of unusualness of extended periods of abnormally wet weather. The completed analysis breaks the meteorological record into separate periods of drought, abnormally wet, or nearly normal. Table 12 lists the descriptive terms which have been assigned to describe the character of the weather represented by various intervals of the Palmer index.

Table 12 - Descriptive Terms for Weather Conditions Represented by Ranges of Palmer Index

Index	Character of Recent Weather
4.00 or more	Very much wetter than normal
3.00 to 3.99	Much wetter than normal
2.00 to 2.99	Moderately wetter than normal
1.00 to 1.99	Slightly wetter than normal
0.50 to 0.99	Incipient wet spell
0.49 to -0.49	Nearly normal
0.50 to -0.99	Incipient drought
-1.00 to -1.99	Mild drought
-2.00 to -2.99	Moderate drought
-3.00 to -3.99	Severe drought
-4.00 or less	Extreme drought

Palmer's technique has been widely used in the United States and in some other areas of the world. Results are reported as being realistic in all areas. The technique is mathematically simple, but it is involved and tedious. When done by hand, it is slow and time-consuming, but where computers are available, results can be attained quickly. The method is better suited for climatological analysis than for operational use. However, during periods when a major drought is developing and spreading, it affords a useful means for routinely assessing the areal distribution of the various degrees of drought severity. In the United States, this is done on a weekly basis during critical situations. Of course, some of the original constants and equations are modified in order to treat weekly rather than monthly data.

Palmer's technique has been applied to the climatic data accumulated since 1931 for each standard climatological division comprising the region. These divisions are shown in figure 43. The regional variations in maximum drought intensity and duration are shown in figure 44. All sections have recorded "extreme" drought with the exception of the southwest and west central divisions of Louisiana. Inspection of figure 44 reveals that durations of the longest "dry" spell range from 21 months in south-central Louisiana to 63 months in northeast Arkansas. Over most southern sections of the region, maximum duration of drought conditions has been 2 to 4 years; in most of the northern sections, 3 to nearly 5 years.

Figure 45 shows the regional "wet" experience. All sections have been "very much wetter than normal" on one or more occasions, while the greatest durations of the longest periods of wet conditions range upward from nearly 20 months in southern Arkansas, the upper Mississippi Delta, and southeast Louisiana to more than 40 months in the extreme northern divisions.

Additional details of the climatic variability indicated by the Palmer Index are displayed in figures 46-A, 46-B, and 46-C. The patterns of monthly moisture anomaly show an irregular alternation of wet and dry periods. Extended periods of severe or extreme drought are uncommon, and region-wide occurrences very rare. The droughts of 1936-37, 1941-42, 1954-55, and 1964 are prominent in northern portions of the region, and those of 1952 and 1963 are outstanding in several southern sections. The wet spells centered in 1945-46, 1950, 1957-58, and 1961-62 are outstanding over substantial areas.

Tornadoes

Introduction. Tornadoes are the most violent storms in nature. Local storms of short duration, tornadoes are characterized by an intense vortex in which air spirals, usually in a counter-clockwise direction, around a central, nearly vertical, core. Tornado destructive forces are a combination of high winds and a partial vacuum at the center of the vortex.

Figure 43. Palmer Index: Climatological Divisions

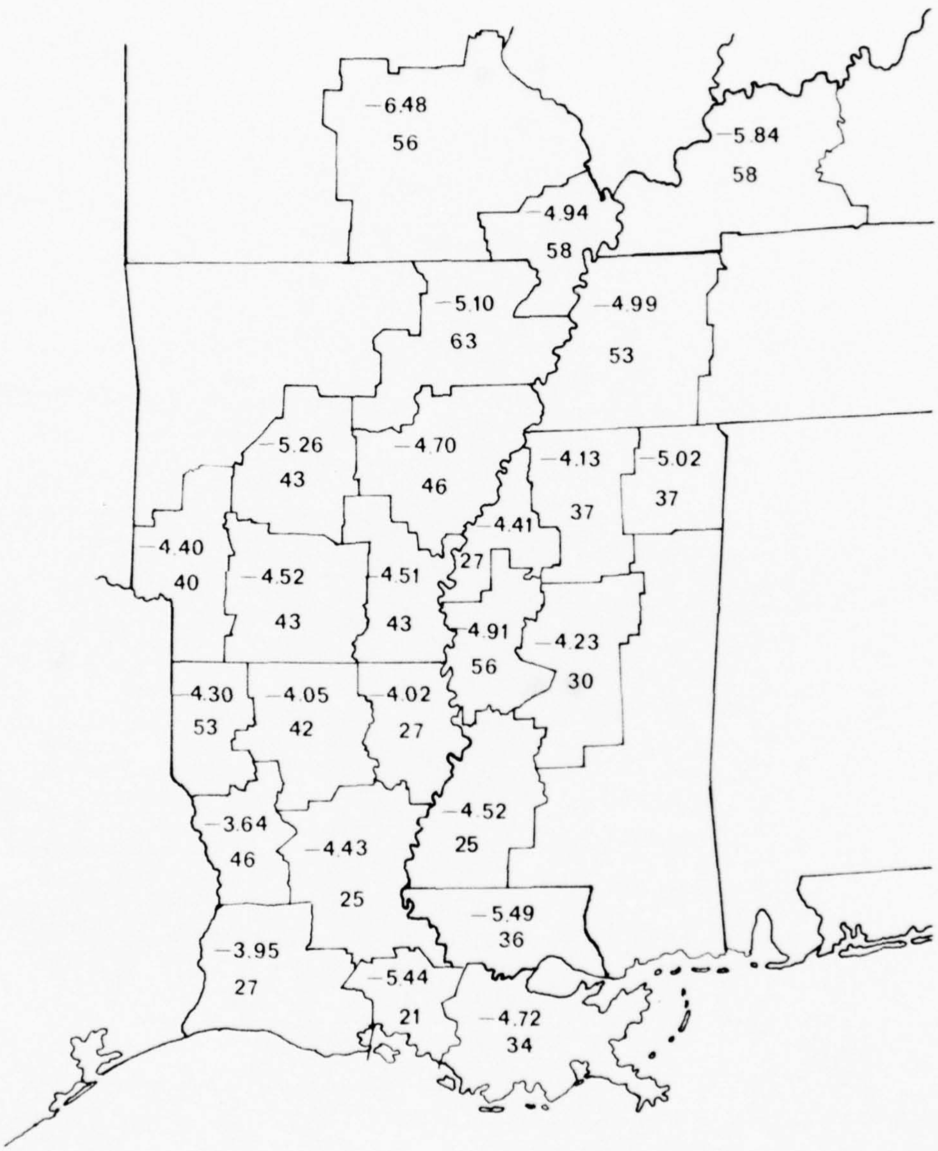


Figure 44. Palmer Index: Value for Driest Month and Duration in Months of Longest Dry Spell, 1931-1970

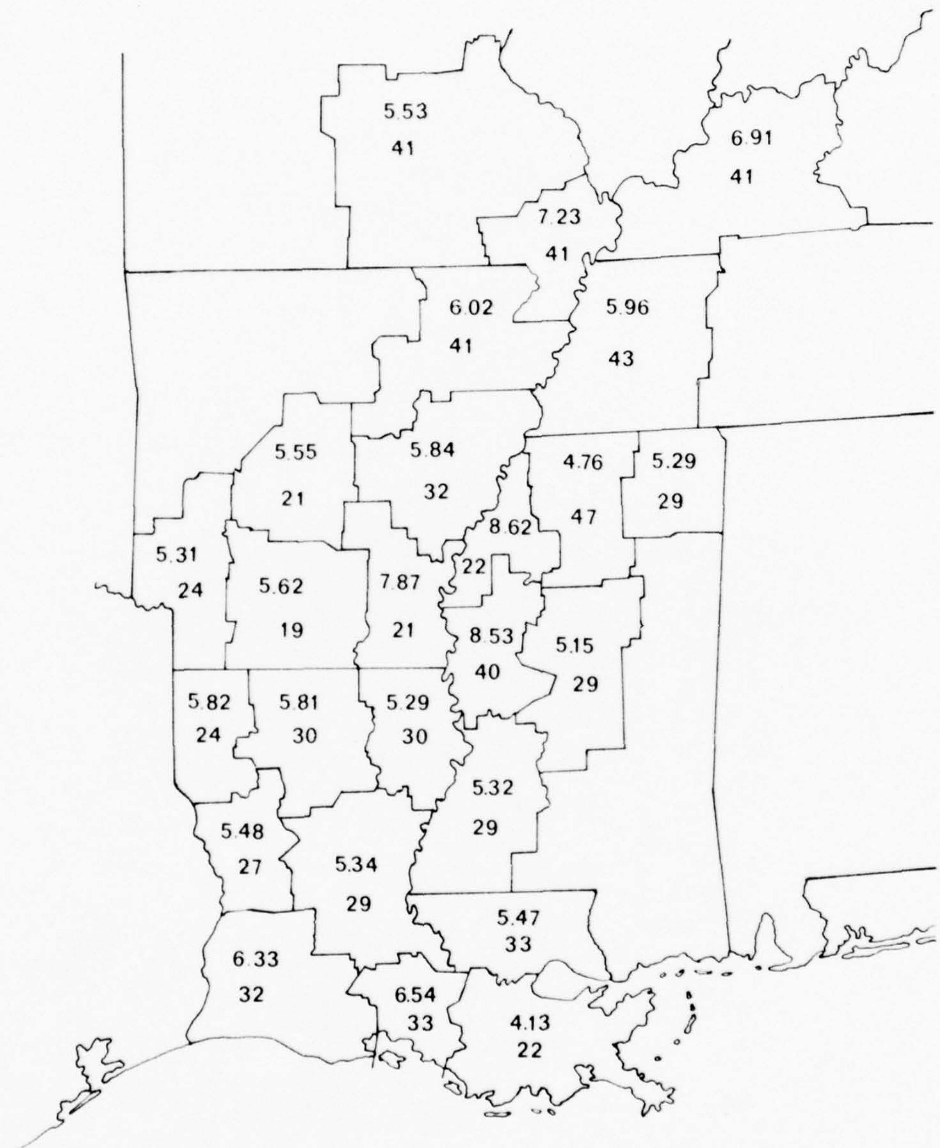


Figure 45. Palmer Index: Value for Wettest Month and Duration in Months of Longest Wet Spell, 1931-1970

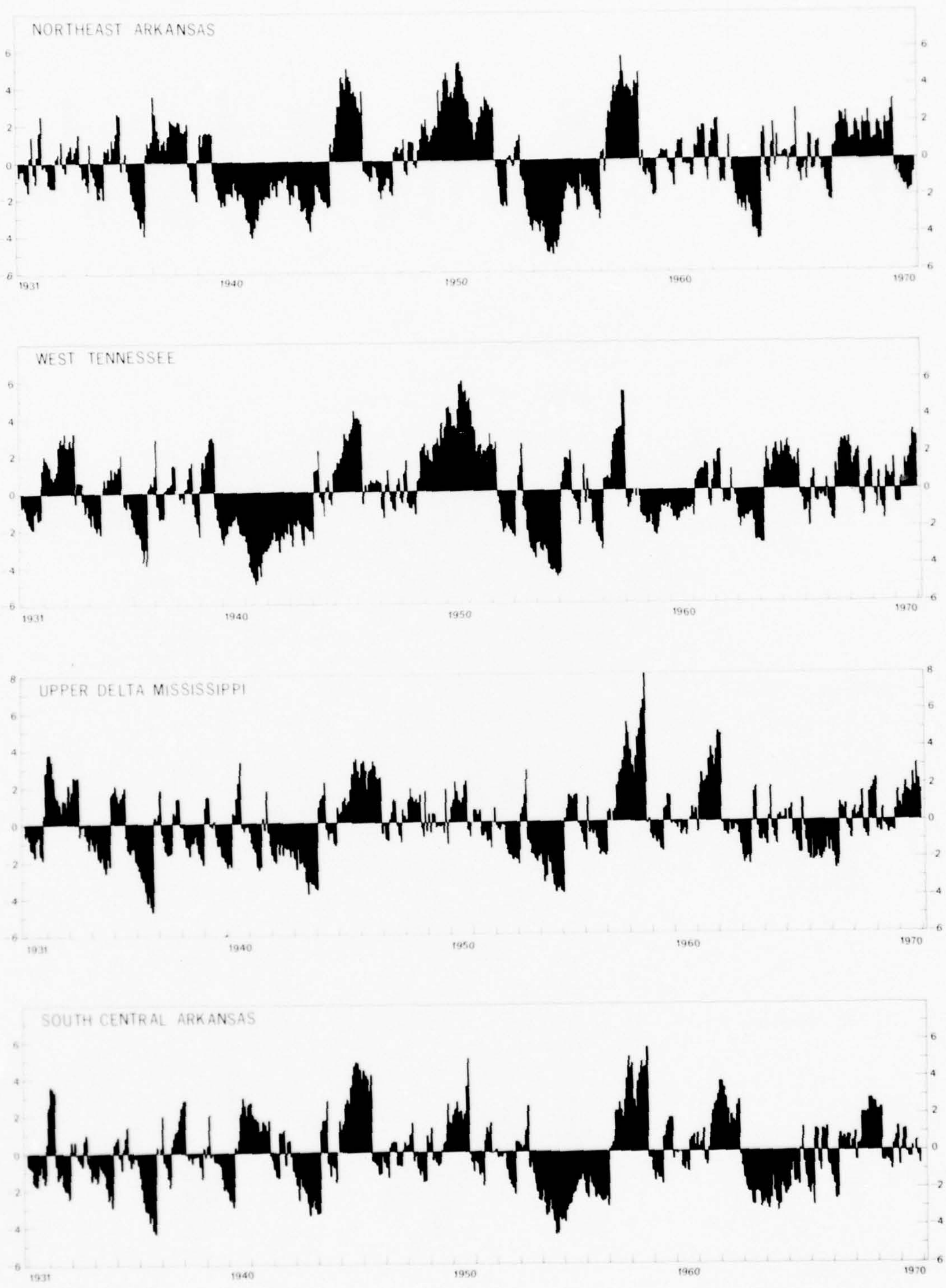


Figure 46-A. Palmer Index: 1931-1970

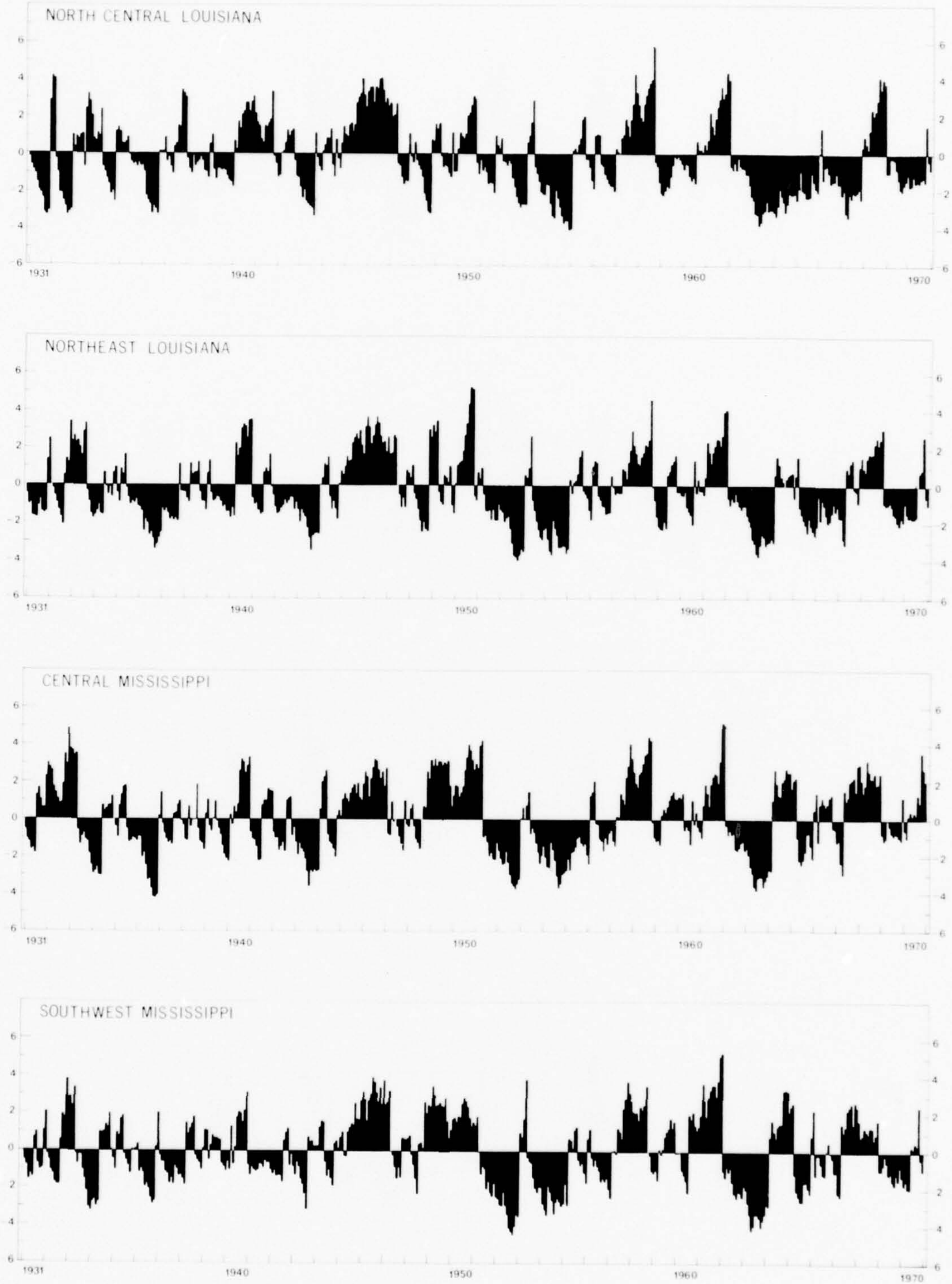


Figure 46-B. Palmer Index: 1931-1970

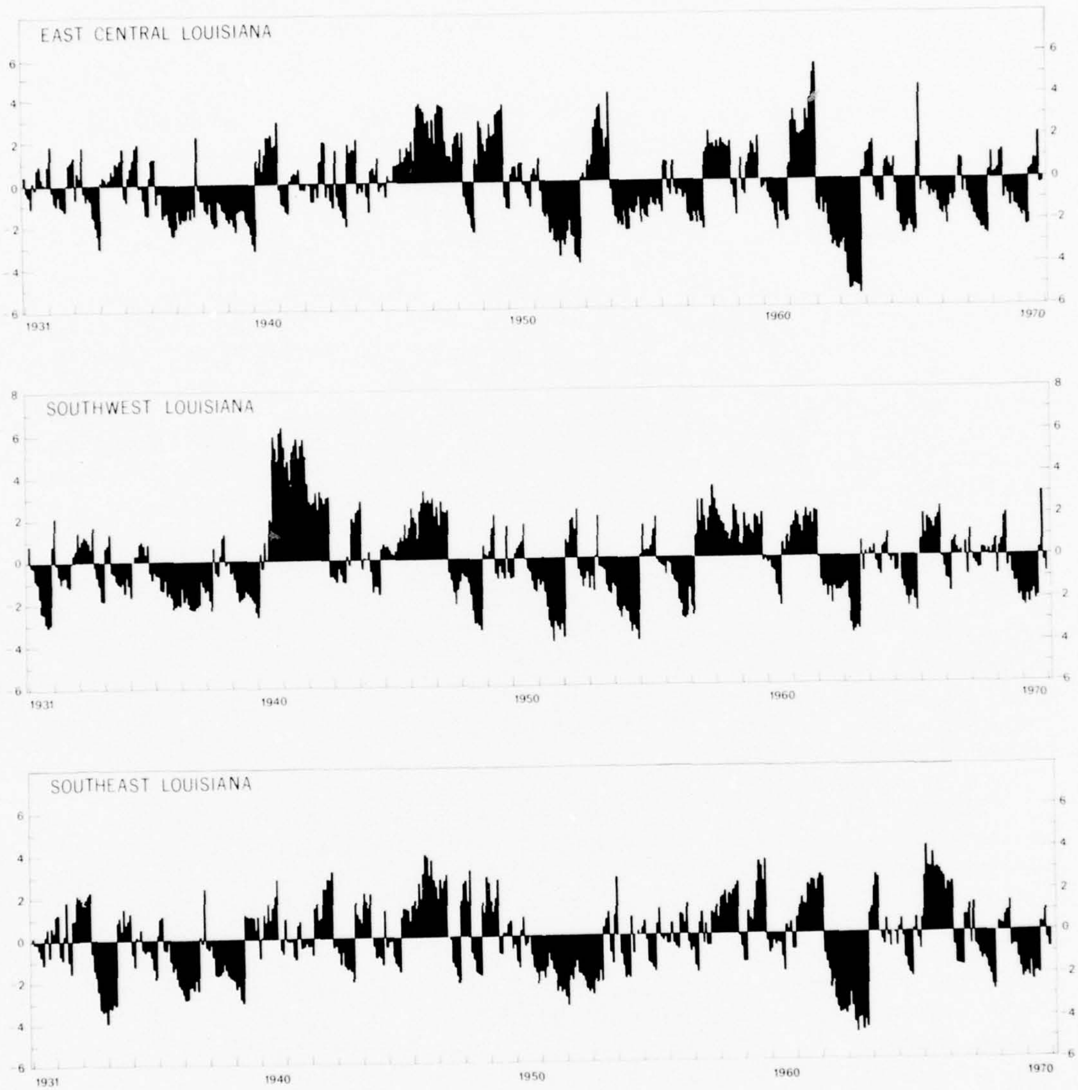


Figure 46-C. Palmer Index: 1931-1970

As a tornado passes over a structure, winds twist and rip at the outside while the abrupt atmospheric pressure reduction produces explosive overpressure inside. Walls collapse or topple outward, windows explode, and debris is driven through the air in a dangerous barrage.

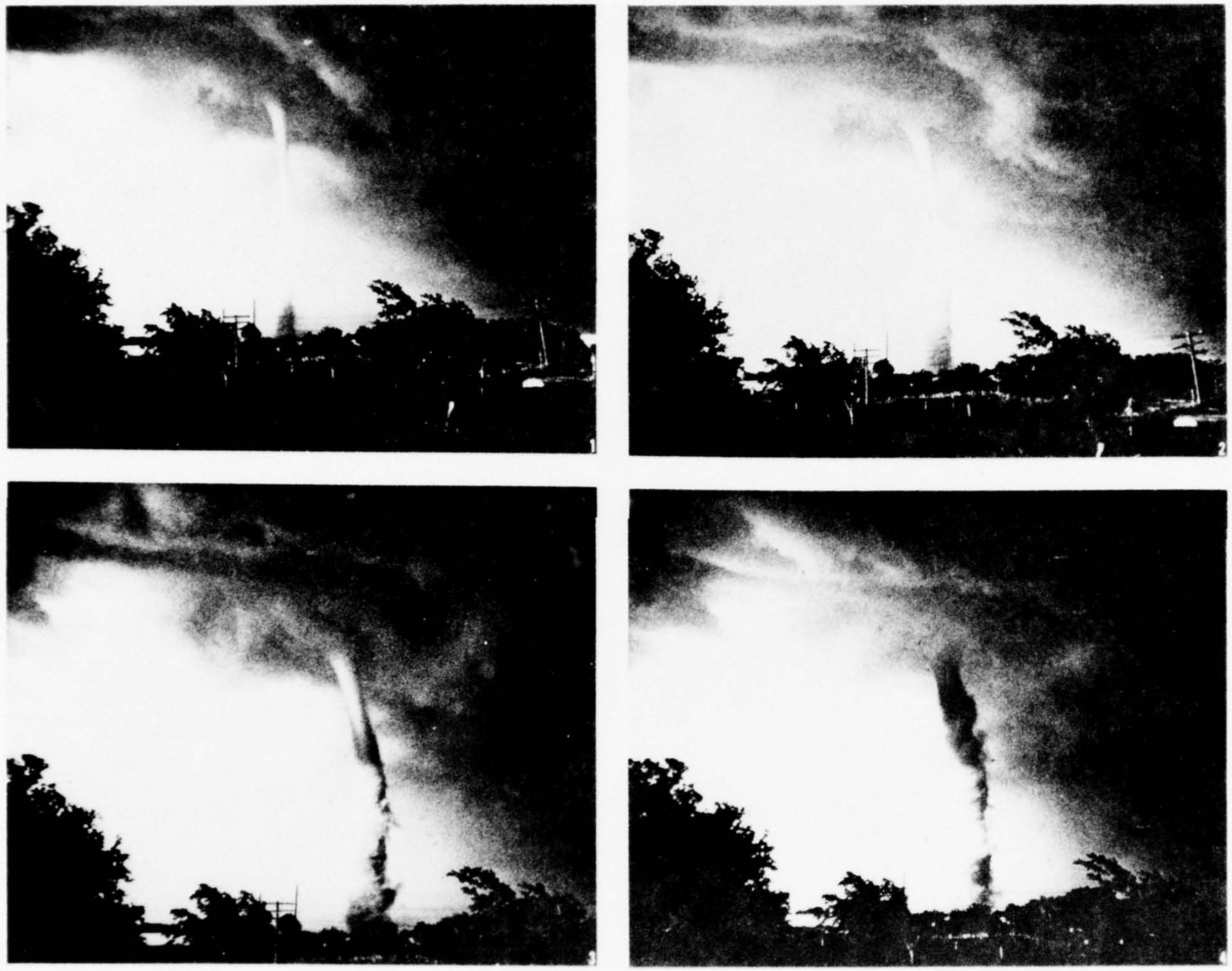
The duration of most tornadoes is brief and their destructive paths are small but often terribly complete. The extreme danger associated with tornadoes is simply that they strike swiftly with terrible force so that warning time allowing evasive action is very short or impossible.

Some phases in the life cycle of a tornado are illustrated in figure 47, a set of photographs taken near Enid, Oklahoma (147). The grayish funnel-shaped cloud characteristic of tornadoes, extends downward from the parent thunderstorm. Often this funnel cloud remains aloft, and the full fury of the storm does not reach the ground. The funnel cloud is produced by the condensation of moisture in the zone of sharply reduced atmospheric pressure. This pressure reduction may be one-sixth to one-quarter of the total pressure.

Tornado paths average less than one-quarter mile in width and are seldom more than 15 miles long. Tornadoes are always associated with parent thunderstorms. When strong squall lines move through a region, several individual tornadoes, a tornado "family," may form in different intense thunderstorm cells. At least four tornadoes moved through the delta region of Mississippi on February 21, 1971, and more than 10 swept Arkansas, Missouri, Tennessee, and Mississippi in the great outbreak of March 21, 1952.

The precise formative mechanisms of tornadoes are unknown. The basic physical processes leading to severe thunderstorms combine to produce thermal instability in the atmosphere, e.g., cold, dense, dry air at higher levels and warm, lighter, moist air at the surface. In this situation, the cold air must descend and the warmer air must rise. This regional atmospheric overturning often results in thunderstorms. More rarely, several meteorological factors combine in exactly the right combination to produce extreme instability, severe thunderstorms, and tornadoes. Such combination is schematized in figure 48. Cold, dry, continental polar air moving southward encounters warm, moist, maritime tropical air along a surface cold front. Aloft, a zone of high-speed winds--a jet stream--overlies the frontal zone of sharp thermal contrast between the air masses. Dry continental tropical air is drawn into the upper level circulation through the jet and acts as the starter for enhancing the instability. Severe weather is most probable within the region indicated by the box in figure 48.

The formation of tornadoes in this basic synoptic flow pattern involves complex transformations of potential energy into kinetic



(Courtesy of National Oceanic and Atmospheric Administration)

Figure 47. Some Phases in the Life Cycle of a Tornado

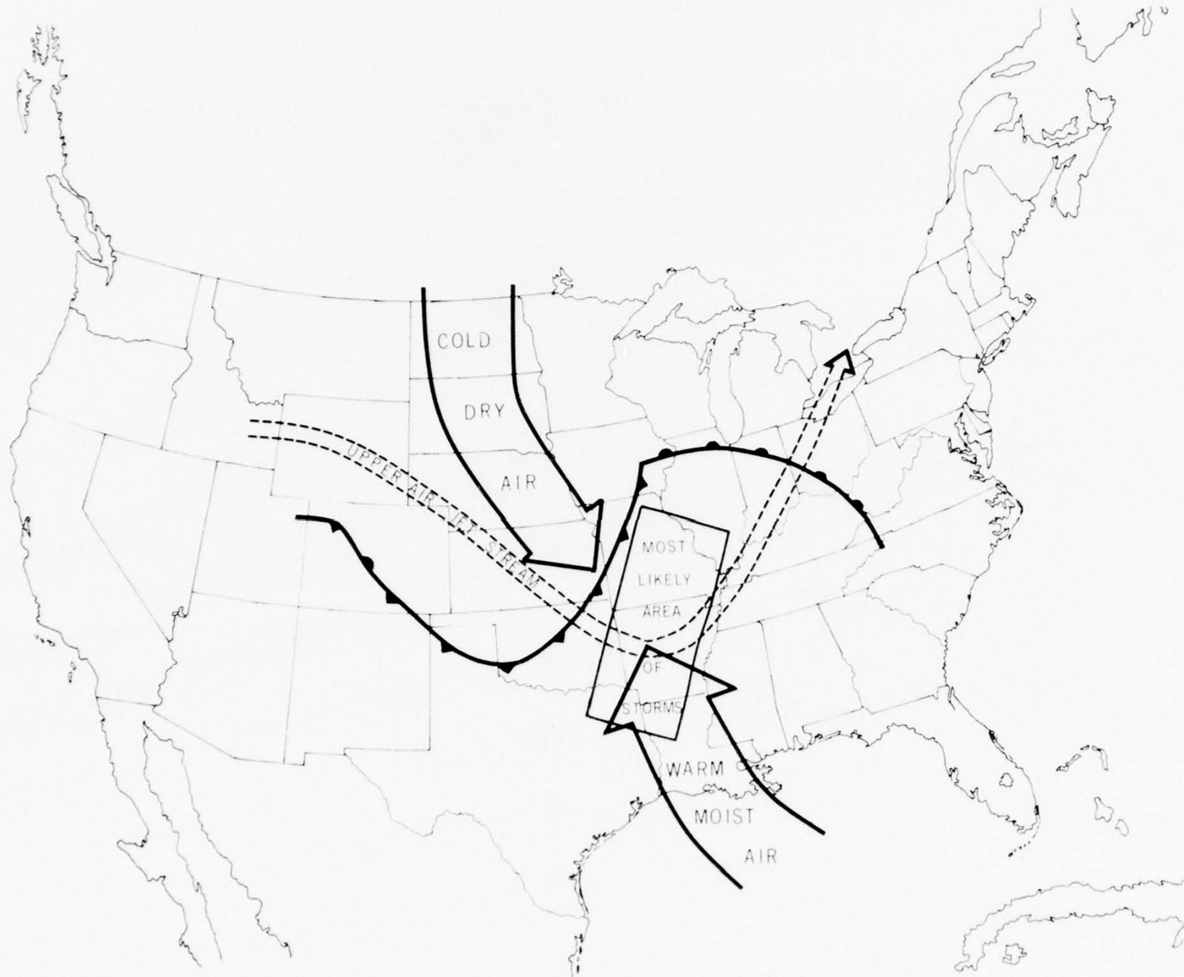


Figure 48. Schematic Illustration of Factors Involved in Development of Severe Local Storms

energy. In some special circumstances, small but intense low pressure areas (micro-lows) form, and the surrounding air begins a spiraling radial inflow. Once the inflow is established, if momentum is conserved, the flow must increase as it approaches the vortex center. The strong convective activity will then sustain the vortex until the kinetic energy is dissipated by friction (150).

While the occurrence of tornadoes has been reported on all the continents except Antarctica, the meteorological conditions necessary to produce the destructive storms are maximized in the Great Plains - Mississippi Valley Region during spring. During the period 1955-1967, an average of more than 600 tornadoes per year was reported in the United States (140). About one-half occur during April, May, and June. Occurrences are most frequent during the warmer part of day due to the convective processes involved. Approximately 23 percent of total tornado activity occurs between 4:00 and 6:00 p.m.; 82 percent occurs between noon and midnight. Wolford (172) provides additional details for the years 1916-1958.

Regional occurrences. The Lower Mississippi Region, located just south and east of the most tornado-prone section in the world, has had numerous tornado disasters. A few of the outstanding tornadoes or tornado families that have occurred in the region during the 20th Century are listed in table 13.

Table 13 - Some Outstanding Lower Mississippi Region Tornado Outbreaks, 1901-1971

Year	Date	Location	Time	Lives Lost	Number Injured	Est. Property Damage
1908	Apr 24 1/	C. and EC. La., S. Miss.	5 a.m.- noon	100	649	$ 880,000
1923	Apr 4	Alexandria-Pineville, La.	5 p.m.	14	---	750,000
1942	Mar 16 1/	C. to NE. Miss.	4 p.m.	75	525	1,400,000
1952	Mar 21 1/	Ark., W. Tenn., N. Miss., SE. Mo.	3 p.m.- mdnt.	204	1184	13,800,000
1953	Dec 5	Vicksburg, Miss.	5:35 p.m.	38	270	25,000,000
1964	Oct 3 2/	Larose, La.	6:30 a.m.	22	165	500,000
1971	Feb 21 1/	NE. La. to WC. and NW. Miss.	3:10-7:30 p.m.	113	2003	19,000,000

1/ Tornado families.
2/ In circulation of Hurricane Hilda.

Figure 49 shows the initial points of reported tornado touchdowns in the Lower Mississippi Region during the years 1951 through 1970 (145). Approximately 5 percent of the total number of United States tornadoes have occurred in the region. Indications of some demographic bias may be noted in this figure. The only positive identification of the tornado is human visual sighting. The maxima noted near centers of population and in areas of intensive rural settlement reflect to an unknown degree the greater numbers of potential observers and reporters in these areas.

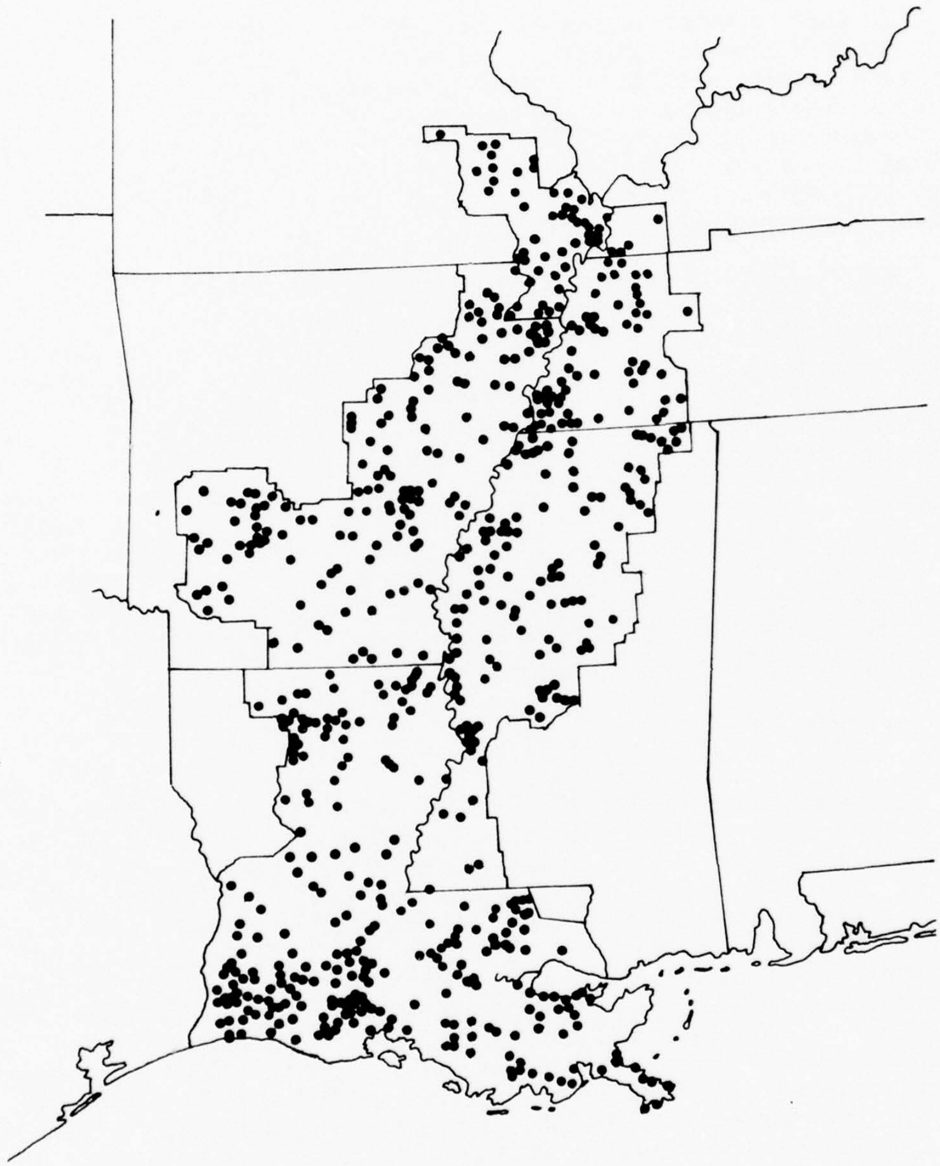


Figure 49. Initial Points of Ground Contact of 624 Verified Tornadoes in Counties Making up the Lower Mississippi Region During the Years 1951-1970

SURFACE WATER

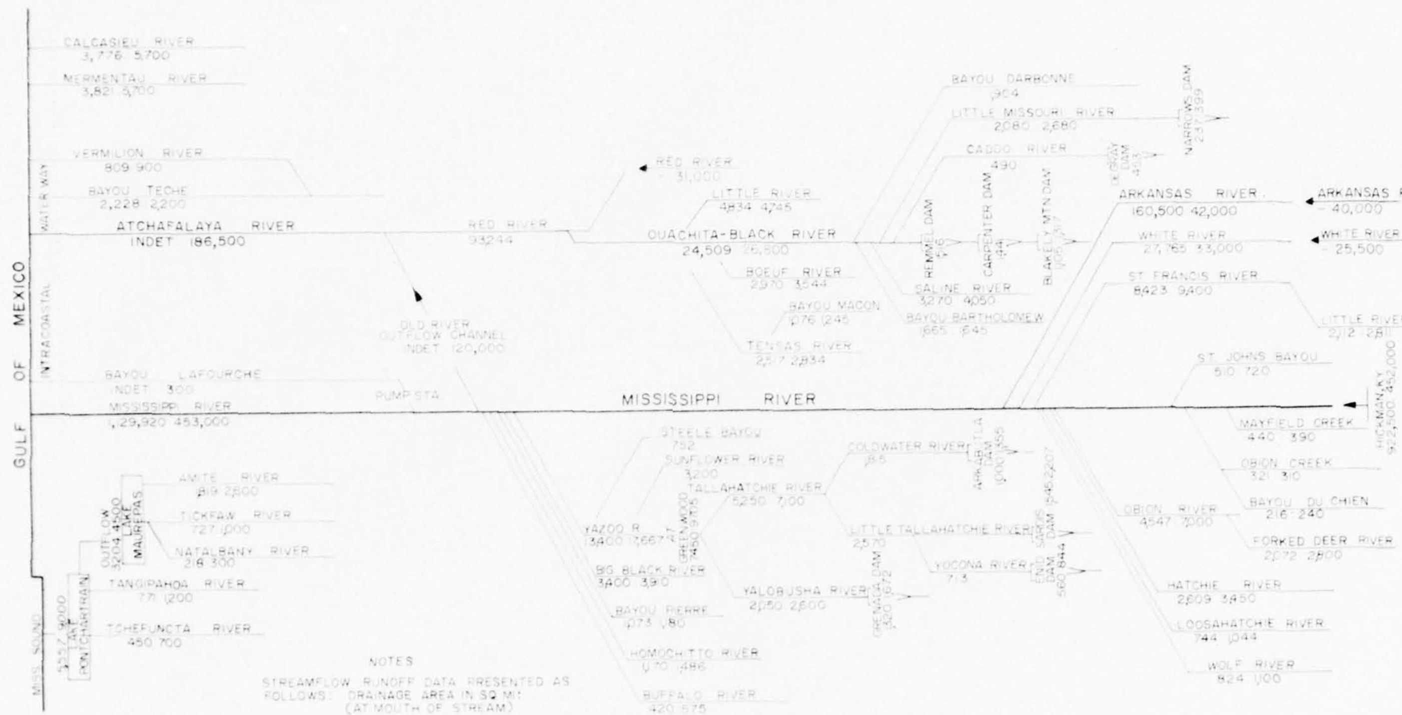
The surface water supply of the Lower Mississippi Region is principally derived from precipitation and runoff within the region, streamflow from sources outside the region, and ground water sources recharging both within and outside the region. Much of the water is stored in ground water aquifers, lakes, surface reservoirs, and streams before flowing to the sea. Water not consumed within the region ultimately flows into the Gulf of Mexico or returns to the atmosphere by evaporation or transpiration.

The streamflow system within the region is composed chiefly of the Mississippi River and its tributary streams between Cairo, Ill., and the Gulf of Mexico and the coastal area streams of southern Louisiana. The total drainage area of streams within the region is about 102,400 square miles, 40,740 square miles of which contribute flow to the Mississippi River. The remaining 52,660 square miles of the region are drained by the Atchafalaya River and other streams which flow into the Gulf of Mexico. A schematic diagram of the pattern of streamflow within the region and the drainage area and mean flows at the mouths of many of the major streams are shown in the area runoff diagram in figure 50. Figure 51 is a regional map showing major lakes and streams, WRPA boundaries, State boundaries, major cities, and other pertinent features. It also presents isopleths of the mean annual runoff generated in the Lower Mississippi Region.

Quantity

The mean annual discharge generated within the Lower Mississippi Region under 1973 levels of development is about 117,380 c.f.s. This is equivalent to about 15.5 inches of runoff or about 85 million acre-feet of runoff per year. About 47 percent of this flow is discharged into the Mississippi River through its tributaries, with the remainder flowing through other routes to the Gulf. About one-half of the flows generated within the region originate in WRPA's 9, 5, and 2. The flows produced in these and the remaining WRPA's are shown in table 14, a tabulation of annual discharges for the Lower Mississippi Region. The Mississippi River and coastal streams in the region collectively discharge an average of about 671,100 c.f.s., or 485 million acre-feet, per year into the Gulf of Mexico. These figures include flows passing into and through the region as well as those generated within the region. About 453,000 c.f.s. are discharged through the Mississippi River, 186,500 c.f.s. through the Atachafalaya River, and the remaining 31,600 c.f.s. through coastal streams in WRPA's 8, 9, and 10.

Major inflow into the Lower Mississippi Region is from the Ohio and Upper Mississippi Regions, which contribute a mean annual flow of



NOTES

STREAMFLOW RUNOFF DATA PRESENTED AS FOLLOWS: DRAINAGE AREA IN SQ. MI (AT MOUTH OF STREAM)
MEAN ANNUAL FLOW IN C.F.S. (AT MOUTH OF STREAM)

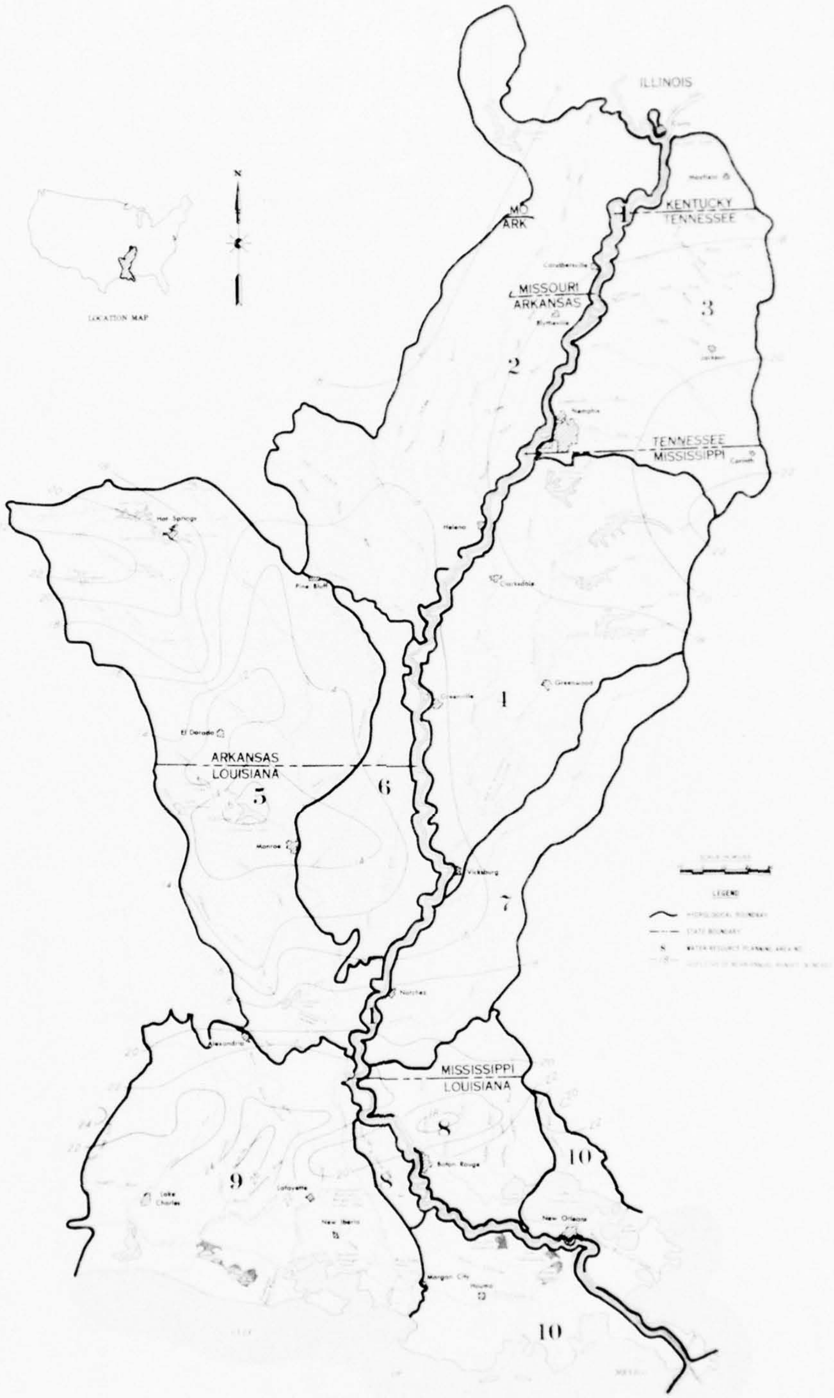
FLOWS AT MOUTHS OF STREAMS ARE ESTIMATED BY DRAINAGE AREA RELATIONSHIP

DUE TO CROSS FLOWS AT VARIOUS STAGES DRAINAGE AREAS AT SOME LOCATIONS ARE INDETERMINATE

SUM OF INFLOWS + GENERATED FLOWS DO NOT EXACTLY BALANCE OUTFLOWS FROM THE REGION DUE TO OMISSION OF FLOWS ORIGINATING IN THE SALT TO BRACKISH MARSHES ALONG THE COAST

LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY
WATERSHED AREA AND
RUNOFF DIAGRAM
THE REGION

FIGURE 50



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN ANNUAL RUNOFF
IN INCHES

FIGURE 51

Table 14 - Mean Annual Discharge for the Lower Mississippi Region, 1973 Conditions

WRPA	Area Square Mile	Mean Annual	Mean Flows in Area (c.f.s.) Exceedence in Percent of Time 80	90	95
1	2,435	453,000 1/	260,000 1/	200,000 1/	170,000 1/
2	16,723	19,770 2/	5,898 2/	4,635 2/	3,999 2/
3	10,653	13,810	2,412	1.996	1,761
4	13,355	17,670	5,550	3,590	2,490
5	20,413	20,440 3/	2,750 3/	1,690 3/	1,245 3/
6	5,520	6,350	580	349	255
7	6,574	7,740	870	677	596
8	5,705	5,700	1,700	1,500	1,400
9	13,297	14,500 4/	4,600 4/	3,300 4/	2,600 4/
Atchafalaya River Outlets	--	186,500	72,800	52,000	41,600
10	7,729	11,400	2,600	1,400	800
The Region	102,404	Flows Generated 117,380	26,960	19,137	15,146
		Flows Thru Region 671,100	341,700	258,200	216,400

1/ Flow for Mississippi River at mouth including inflows into the area from other areas.
2/ Does not include contributions from Arkansas and White River Basins above backwater effects of Mississippi River.
3/ Does not include flows from WRPA 6.
4/ Does not include flows generated within Atchafalaya Floodway.

approximately 452,000 c.f.s. into the region. Additional inflows to the region average 25,500 c.f.s. from the White River Basin, 40,000 c.f.s. from the Arkansas River Basin, and 31,000 c.f.s. from the Red River Basin.

The mean annual discharge values discussed in the preceding paragraphs represent the ultimate quantity of water from the region that can be made available for use. However, this quantity can never be realistically obtained for use because of the physical limitations of available storage sites and increases in natural losses that occur with

development. The availability of surface water within the region can be defined on a percentage basis, such as the flow equaled or exceeded for various periods of time. For general planning purposes, dependable yields at potential reservoir sites should be considered as the lowest mean annual flow for the period of record, or about the 90 percent duration flow. Flows for durations of 80 and 95 percent should also be considered. In the Lower Mississippi Region, a discharge of about 341,700 c.f.s. can be expected to occur about 80 percent of the time, 258,200 c.f.s. about 90 percent of the time, and 216,400 c.f.s. about 95 percent of the time. These flows include inflows from outside the region. These duration figures and those for each WRPA are given in table 14.

Present Utilization

Withdrawals from surface water sources in the Lower Mississippi Region during 1970 averaged about 22,265 c.f.s. and were equivalent to about 19 percent of the mean annual flow generated within the region (117,380 c.f.s.). Surface water withdrawals constituted about 74 percent of the total withdrawals in the region, with the remainder coming from ground water sources.

Major surface water withdrawals were from WRPA 10, which withdrew 40 percent (8,765 c.f.s.) of all the surface water withdrawn in the area. The coastal areas, WRPA's 8, 9, and 10, together accounted for about three-fourths of the region's total surface water withdrawal, with most of the water being used in the rapidly expanding basic metal and petrochemical industries in the New Orleans-Baton Rouge, La., area. Major purposes of surface water withdrawals were for industrial uses (7,120 c.f.s.), power production (6,915 c.f.s.), and fish and wildlife enhancement (4,870 c.f.s.).

Ground water withdrawals in the region during 1970 averaged about 8,290 c.f.s. About 45 percent of these withdrawals were from WRPA 2 and were used for irrigation of crops. Irrigation was also the leading use of ground water withdrawals in the entire region, averaging 5,390 c.f.s. during 1970. Industrial and municipal withdrawals totaled 1,280 and 625 c.f.s., respectively.

About 12,120 c.f.s., or 40 percent of the total ground and surface water withdrawals from the Lower Mississippi Region, were consumed. The remaining 18,435 c.f.s. that were withdrawn were released and returned to streamflow. These releases resulted in a net decrease in streamflow in the region of about 3,830 c.f.s.

The areas consuming the largest quantities of water were WRPA's 10, 2, and 9, which together accounted for over 75 percent of the total consumption of water in the region. Major consumptions were for irrigation (5,260 c.f.s.), fish and wildlife enhancement (4,245 c.f.s.), and industrial uses (1,310 c.f.s.).

Additional information on the withdrawals of ground and surface water in the Lower Mississippi Region during 1970 is given in table 15. Also presented are pertinent data on the consumption of water in each area and in the entire region.

Table 15 - Water Use in 1970, Lower Mississippi Region (c.f.s.)

WRPA 1/	Municipal	Industrial	Power Production	Irrigation	Other Agriculture	Commercial Fishing	Mineral Industry	Fish and Wildlife	Rural Domestic	Total c.f.s.
					Surface Water Withdrawn					
2	3.26	7.9	610.7	412.3	1.6	2.3	5.6	809.1	0	1852.8
3	0.0	5.4	666.5	38.1	5.1	.9	1.1	134.9	0	852.0
4	0.0	58.1	424.6	193.4	8.4	21.7	1.2	24.0	0	731.3
5	26.0	135.5	1659.6	183.5	7.4	10.4	14.7	374.1	0	2411.1
6	.9	51.3	0.0	57.3	3.7	4.0	1.2	98.7	0	217.1
7	0.0	.8	0.0	1.2	3.7	1.7	.7	3.9	0	12.0
8	1.6	2095.6	899.0	0	0	1.6	43.4 2/	3.1	0	3044.2
9	10.9	1647.4 2/	508.4	1176.5	0	51.2	421.6 2/	562.7	0	4378.8
10	277.3	3118.7 2/	2146.8 2/	0	0	7.8	358.1 2/	2856.7	0	8765.3
	320.0	7120.7	6915.6	2062.3	29.9	101.6	847.6	4867.2	0	22264.6
					Ground Water Withdrawn					
2	50.7	52.2	7.8	3441.0	6.2	13.2	.6	90.0	38.3	3700.0
3	207.7	146.6	0	6.8	7.6	4.8	.5	15.5	29.9	419.4
4	83.4	76.1	48.2	267.0	5.6	87.9	.5	24.0	33.6	626.3
5	58.1	184.9	.5	385.4	5.0	24.3	70.6	19.7	24.9	773.4
6	11.6	44.0	.5	181.4	2.5	9.5	9.8	5.2	10.4	274.8
7	18.6	113.3	1.5	11.2	2.5	7.0	4.9	3.9	8.0	170.9
8	85.3	251.1 2/	14.0 2/	4.7	7.8	1.6	0	1.6	7.00	372.8
9	100.8	368.9	14.0	1081.9	10.9	52.7	0	187.6	26.0	1843.0
10	9.0	40.8	33.2	7.8	1.6	4.7	0	3.1	5.4	107.0
	625.2	1277.9	119.7	5387.2	49.7	205.7	86.9	350.6	183.5	8287.6
					Water Consumed					
2	20.0	24.0	3.9	2808.6	7.8	1.6	0	181.4	38.3	3085.6
3	77.2	22.6	9.3	31.9	12.7	.6	0	29.5	29.9	214.0
4	31.0	11.0	4.2	341.0	14.0	104.0	.8	48.1	33.6	587.7
5	31.3	105.7	15.2	440.5	12.4	33.0	13.7	393.7	25.0	1070.4
6	4.7	10.1	.5	179.0	6.2	12.9	3.2	103.9	10.4	330.6
7	7.0	9.3	.9	10.5	6.2	8.2	5.5	7.8	8.1	63.4
8	32.6	598.3	58.9	3.1	7.8	3.1	12.4	3.1	2.5	721.7
9	41.9	358.1 2/	34.1	1441.5	10.9	99.2	12.4	618.5	9.2	2625.7
10	107.0	172.1 2/	130.2 2/	4.7	1.6	12.4	133.3 2/	2858.2	2.0	3420.9
	352.7	1311.2	257.2	5260.8	79.6	275.0	181.3	4244.2	159.0	1212.0

1/ Withdrawals from WRPA 1 were allocated to adjacent WRPA.
2/ Include withdrawals from brackish water sources.

Stream Management

Stream management practices include the measurement, regulation, and conservation of the water resources within the region. Considerable progress has been made in making these practices more efficient for the benefit of all the various water users. This progress has been mainly through the development of means to physically control the streamflow, through the development of criteria for use in planning the regulation of streamflow, and through work on the legal aspects involved in controlling streamflow.

The physical control and management of the streams involve the construction and operation of storage and diversion facilities, such as

flood-control reservoirs and locks and dams on the major navigation channels, and channel modification and maintenance to control drainage.

The operation of reservoirs for flood control usually follows a pattern of discharging excess water in the early months of the fall, then maintaining active capacity during the winter months to allow for the storage of runoff from heavy winter and spring rains. The stored water is then released as needed for power generation, water supply, pollution abatement, and other purposes in the channels downstream. Frequently, the releases needed to supplement low flows in the summer months may lower the reservoirs to the point that no excess water will have to be released to maintain active storage prior to the flood season. These releases during the low flow season are based on predictions of reservoir levels through use of rainfall data, reservoir inflow and release rates, river stage data, and minimum release rates allowable at the site. Maximum releases during flood periods are usually restricted by the ability of the downstream channel to carry the flows. On the power generating reservoirs, a rule curve and method of operation have been developed which allow the most advantageous use of the streamflow available at each of the respective sites. The water used for power generation is also used for other purposes downstream. Releases for the generation of power during flood periods are limited to prevent their possible contribution to excess discharges which could result in flooding downstream.

Diversions. The major diversions of water in the region are for irrigation and for fish and wildlife enhancement. Many of the main agricultural areas rely on stream diversions to augment a deficient water supply during the growing season. The largest irrigation withdrawals are made in WRPA's 9, 2, 4, and 5 (table 15). Major crops irrigated are cotton and rice. The use of water for fish and wildlife enhancement involves the diversion of water into temporary impoundments during the fall and winter to serve as feeding areas for migratory waterfowl and the diversion of water for fish ponds and commercial fish hatcheries.

Channel modification and flood-control works. Channel modification and related projects have a significant effect on the discharge of various streams in the region. Most of the modifications involve flood control, navigation, and conservation, and include levees, revetments, dikes, channel shortening and enlargement, and dredging. This work is undertaken only when the project is proved to be justified from an economic standpoint.

Principal channel modification works in the region include improvements along the entire length of the Lower Mississippi River for navigation and flood protection. The work on the main stem consists of cutoffs to shorten the river and reduce flood stages, revetments to stabilize the channel and stop the river's meandering, dikes to direct flow and regulate channel alignment, and dredging to realign the

channel and provide necessary depths for navigation. These improvements are discussed in detail in the channel improvement section of WRPA 1.

Major tributary improvements consist of levees, floodwalls, pumping stations, storage reservoirs, channel enlargements, and floodways to provide flood protection, navigation, recreation, and water supply within the tributary basins. Work in the upper part of the region consists of the operation and maintenance of the Wappapello Dam and Lake and levee and channel improvement works in the St. Francis River Basin in Arkansas and Missouri, the Obion and Forked Deer Basins in Tennessee, and the White River Basin in Arkansas. The White River Backwater Levee and Graham Burke Pumping Plant serve to protect about 145,000 acres of alluvial farmland from annual flooding [122]. A navigation channel is maintained on the White River from the mouth to the vicinity of Augusta, Ark.

On the streams of the central part of the region, principal works include the maintenance and operation of the Ouachita and Black Rivers 9-foot navigation project, the multipurpose Blakely Mountain Dam on the Ouachita River, Narrows Dam (Lake Greeson) on the Little Missouri River, and DeGray Dam and Lake on the Caddo River. Work in the Yazoo Basin in Mississippi consists of the maintenance and operation of four flood-control lakes--Arkabutla, Enid, Sardis, and Grenada, and downstream flood-control and channel improvements works on the Yazoo River and its tributaries. Extensive drainage improvements have also been completed or are under construction in the Boeuf and Tensas Basins in Arkansas and Louisiana and the Big Sunflower Basin in Mississippi.

Principal works in the lower part of the region include construction of a system of flood-control features, such as levees, revetments, and floodways, below the Old River which are capable of safely passing flood flows through the area. This system is discussed in the Project Design Flood and Floodways sections of WRPA 1. Numerous small flood-control works are under construction along with four large hurricane protection projects in the coastal areas. Navigation work is maintained on the various passes of the Mississippi River at the mouth, along the Gulf Intracoastal Waterway, and on the Calcasieu River below Lake Charles in southwestern Louisiana.

Forecasts. The River Forecast Center (RFC) of the National Weather Service at Slidell, La., provides comprehensive river forecasting and warnings services for the Lower Mississippi Region. The RFC daily processes meteorological and hydrological information through a computerized model, obtaining stage and crest forecasts at many points. Crest forecasts range from a few hours in advance for small drainage areas to two to three weeks in advance for downstream points on the major streams. Weather Service River District Offices (RDO's) in Cairo, Ill., Memphis, Tenn., Little Rock, Ark., Jackson, Miss., and Shreveport, Lake Charles, and New Orleans, La., are responsible for the preparation of

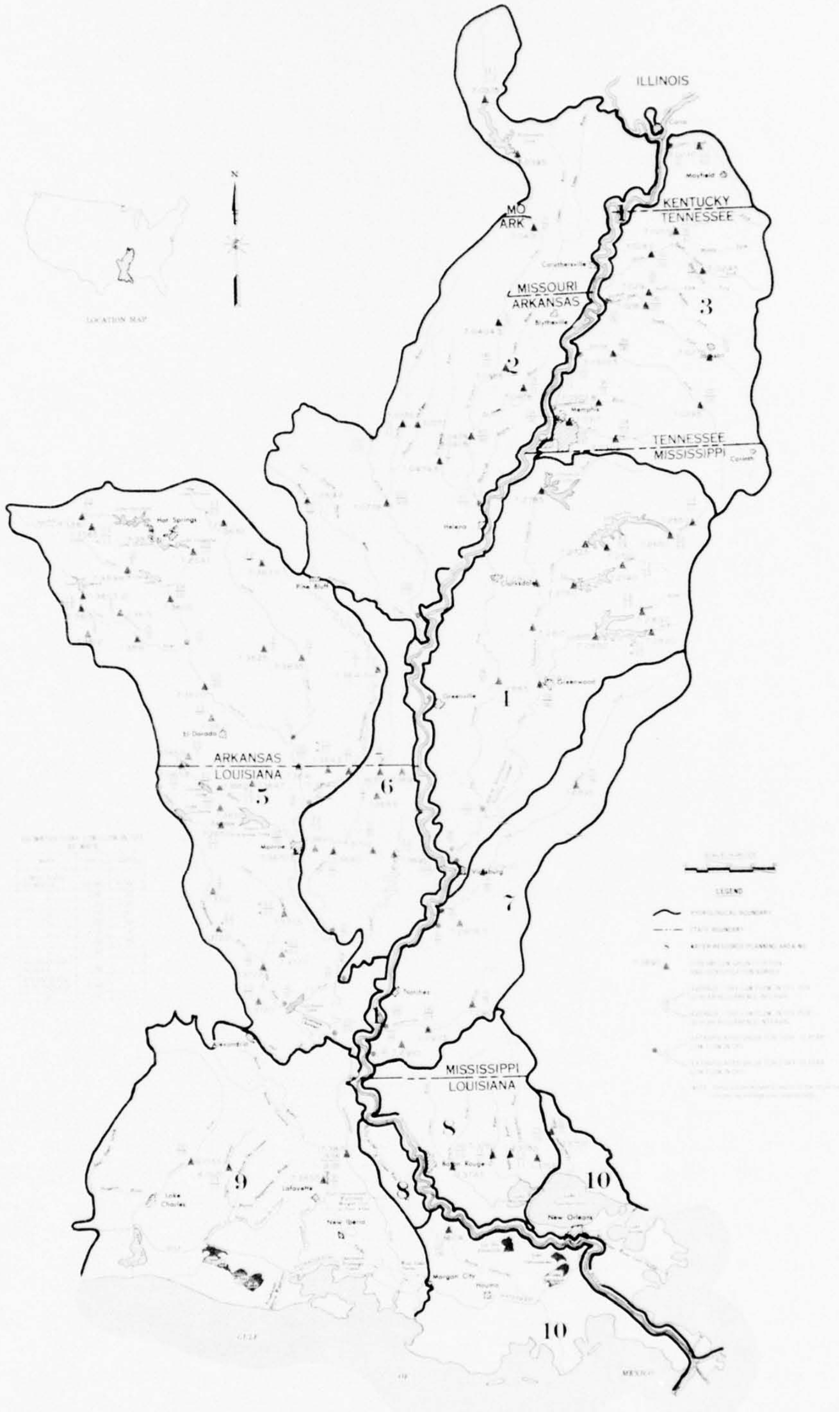
preliminary flood warnings and the dissemination of forecasts and warnings supplied by the RFC; for data collection for the RFC; and for liaison with other agencies to keep abreast of forecast needs and changes in reservoirs, flood-control works, etc., that may affect river stages.

Streamflow

Various periods of flow at selected gaging sites within the Lower Mississippi Region are presented in this report because of the availability of discharge data at the sites. The streamflow for the available period of record at each site was considered to be representative of the various drainage and hydrologic conditions which exist in the surrounding area and reflect regulation and use under 1973 levels of development. At sites which have been recently regulated and at which streamflow data were obtained from a period of record too short to be statistically sound, the flows were adjusted based on routings of the past flows at the sites under regulated conditions.

The selected sites were chosen to assist the various agencies who prepare the fundamental appendices of this report by providing detailed data on each of the streams of interest. This information was also compiled to serve as a guide to plan formulation in satisfying the projected water needs in each part of the region.

Measurement facilities. Streamflow data at 102 sites in the region were selected for presentation in this appendix. The specific locations of these sites are shown on the map of low flows at selected sites in the region in figure 52 and on the mean annual runoff maps in each WRPA section and are identified by the U. S. Geological Survey station numbers which are commonly used in the USGS annual publications. The stations are numbered in a downstream direction along the main stem of the streams. The full station number may contain eight digits, the first of which, or first two if greater than nine, represents the part number (a number which is assigned to a large area covered by one volume of the Water Supply Paper series published by the USGS) and the remaining six, the last two of which are usually decimals, represent the specific gaging location. In cases where the two decimal digits are zeros, one or both of them may be dropped. The names of the respective sites, along with the station numbers, controlling agencies, gage data, drainage areas, period of records, mean flows, extremes of stage and discharge, and other pertinent hydrologic data, are given in the "Streamflow Summary for Selected Sites" in each WRPA section. The mean annual flow values are average flows for the base period at the selected sites and reflect regulation and use under 1973 levels of development. The extreme stage and discharge values are observed values for the entire period of record available at the gaging stations, and, for certain cases, may be affected by regulation. The discharge values usually correspond to the crest stage obtained by use of a recording gage or a nonrecording gage read at the time of the crest. All elevations given throughout this report are in feet referred to mean sea level.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

SEVEN DAY LOW FLOWS AT SELECTED SITES

FOR RECURRENCE INTERVALS OF 10 AND 30 YEARS (7 DAY Q_{10} AND 7 DAY Q_{30})

FIGURE 52

Pertinent data on the drainage area and mean annual discharge for each WRPA are shown in table 14 and on the area-runoff diagram in figure 50. Isopleths of mean annual runoff for the region are shown in figure 51. The discharge for each WRPA represents the flow which is generated within that area, or the outflow of the WRPA minus the inflow. Also shown in this table are the approximate flows that would be available 80, 90, and 95 percent of the time under 1973 levels of development and utilization.

Average discharge for the region. The mean annual discharge generated within the Lower Mississippi Region is 117,380 c.f.s. The major portion of this flow is generated within WRPA's 9, 5, and 2. The mean annual flow which passes through the region and is discharged into the Gulf of Mexico is about 671,100 c.f.s. About 453,000 c.f.s. is discharged through the Mississippi River, 186,500 through the Atchafalaya River, and the remaining 31,500 c.f.s. through the tributary streams of WRPA's 8, 9, and 10.

In each WRPA section (except WRPA's 8, 9, and 10) a figure showing the monthly discharge generated within the WRPA is presented. This figure presents the mean monthly discharge generated within the area for the maximum, mean, and minimum months, and for monthly flows exceeded 20 and 80 percent of the time. These flows were derived by taking the respective discharge data at key stations in each area and adjusting the data to apply to the area as a whole. For estimating purposes, the high or low water flows for probable occurrences other than 20 or 80 percent of the time may be obtained from curves drawn through plots of the maximum (0 percent), 20 percent, mean (approximately 50 percent), 80 percent, and minimum (100 percent duration) discharges.

Average discharge for selected stations. Detailed data on the average discharge at each of the selected sites are presented in the WRPA sections of this report. Tables of mean flows by months for each site are given in the surface water sections. These flows are based on observed flows and are given for a period of record which reflects regulation and utilization under 1973 levels of development. A streamflow summary in each WRPA section presents a list of the selected gaging sites, the controlling agency and station number at the site, the drainage area above the site, the period of record for which discharge data were available, and pertinent stage and flow data at the site.

Specific details regarding the use of the data common to each WRPA are discussed below rather than in each of the individual WRPA sections of this report. Much of the discharge information given in the surface water sections was calculated by computer analysis using discharge data on magnetic tapes. The U. S. Geological Survey was responsible for most of the data collection and the preparation of the magnetic tapes. Both USGS and Corps of Engineers computer programs were used to analyze this data.

Peak flow frequency curves for many of the selected sites in the area are shown in the WRPA sections. These curves are a reflection of the annual peak discharge at the stations and were computed using the log Pearson Type III procedure [6]. No peak flow frequency curves were computed at stations immediately downstream from reservoir sites because of the effect of regulation on peak flows. Curves were not computed at some sites because the periods of record were too short to give a true statistical representation of the peak flows at the sites.

Low flow frequency curves were computed for most of the selected sites in the region and are shown in the WRPA sections. These curves are a statistical representation of the lowest mean flows for periods of 3 to 120 consecutive days which can be expected to occur at the sites for recurrence intervals from 1 to 50 years. No low flow frequency curves were computed at sites directly below the reservoirs because of the large variations in low flow due to regulation of the reservoirs. At certain sites on streams regulated by locks and dams, accurate low flow measurements were difficult to obtain; hence, no low flow frequency curves were computed at these sites. A summary of the seven-day low flows for 10- and 30-year recurrence intervals at selected sites is presented in figure 52.

The low flow frequency curves can be used to determine the dependable supply of surface water without storage in a stream. The slope of the low flow frequency curves is a reflection of the geologic and hydraulic characteristics of the drainage area. The slope and magnitude of flows on the seven-day curves, which are usually affected by ground water flows, indicate the amount of ground water storage available to sustain streamflow. A flat slope indicates that a relatively large amount of ground water is available, and a steep slope indicates that either a small amount or no ground water discharge is available [104].

Duration curves for daily flows at many of the selected sites within the region are shown in each of the WRPA sections. These curves are essentially cumulative frequency curves that show the percentage of time that specified discharges were equaled or exceeded at the site during given periods of record. These curves indicate flow characteristics of a stream throughout its entire range of discharges, without regard to the sequence of occurrence. The maximum daily flows are listed on the curves due to lack of space required to extend the curves to the zero percent exceedence point.

Future long-term flow patterns for a stream can be reliably predicted from discharge duration curves if no unusual climatological or manmade changes occur. The curves can be used for direct comparison of flow characteristics of different streams or of different points on the same stream on a flow per square mile of drainage area basis. The curves are commonly used by water resources planners as a guide to define the water availability at a specified site on a stream.

The slope of the duration curve is a quantitative measure of the variability of the discharge in a particular stream. A flat slope on the lower end depicts a well sustained flow or a stream with a relatively high yield. The overall slopes of the curves for streams having large low flow yields are usually flatter than those for streams having small low flow yields [105].

The duration curves can also reflect characteristics of regulation in a stream. Regulation can be detected on the duration curves by the flattening of the curves in the middle (30-70 percent) exceedence ranges. The reservoirs produce this change in flow characteristics by reducing the peak flows and by increasing low flows at the site for a large percent of the time. This is illustrated by the duration curves for sites below the reservoirs in WRPA's 4 and 5.

Dependable yield characteristics of streams in the Lower Mississippi Region are presented in tables in the WRPA sections of this appendix. The tables give the lowest recorded mean flows for periods of 1 to 10 consecutive years, both in absolute numbers and as a percentage of the mean flow for the period of record. In general, the minimum mean annual discharge on Mississippi River tributaries averaged about 34 percent of the mean annual flow and ranged from a high of 84 percent to a low of 9 percent of the mean annual flow at most of the stations. These percentages do not reflect conditions on streams with short periods of record or small drainage areas.

The mean annual discharge is the ultimate quantity of water available for use in a basin. However, physical limitations of available storage sites and increases in natural losses that occur with development make it impossible to obtain this quantity of water. In most of the basins of the Lower Mississippi Region, potential storage sites which could approach ultimate storage development do not exist. The dependable yield data presented in the WRPA sections and the preceding paragraphs indicate that the use of the mean annual flow to determine the total quantity of water available is not realistic. Instead, dependable yields from potential reservoir sites for preliminary planning purposes should be considered as the lowest mean annual flow which occurred in the period of record at the site or about the 90 percent duration flow. These figures give a more practical measure of the total quantity of water that could consistently be made available for use at a given site.

Variation in precipitation and discharge. Variations in precipitation causes both long-term and seasonal variations in discharge on all the streams within the region. Long-term variations in precipitation and discharge at several of the major selected sites in the region are shown in the WRPA sections. The mean and 5-year moving averages of both precipitation and discharge are presented in the figures. The 5-year moving averages were computed to illustrate the general trend of the

relationship between precipitation and discharge at the selected sites.

Seasonal variations in runoff and streamflow are caused directly by variations in rainfall. The monthly discharge hydrograph for the region and those for each WRPA depict this variation. The larger seasonal flows in the area usually occur during the months of February to May. This is caused by the heavy winter and spring rains over the immediate area and the increased flow from meltwater in the neighboring regions. Low streamflow usually occurs during July to November. This is generally attributable to the small amount of rainfall over the immediate area at this time of year.

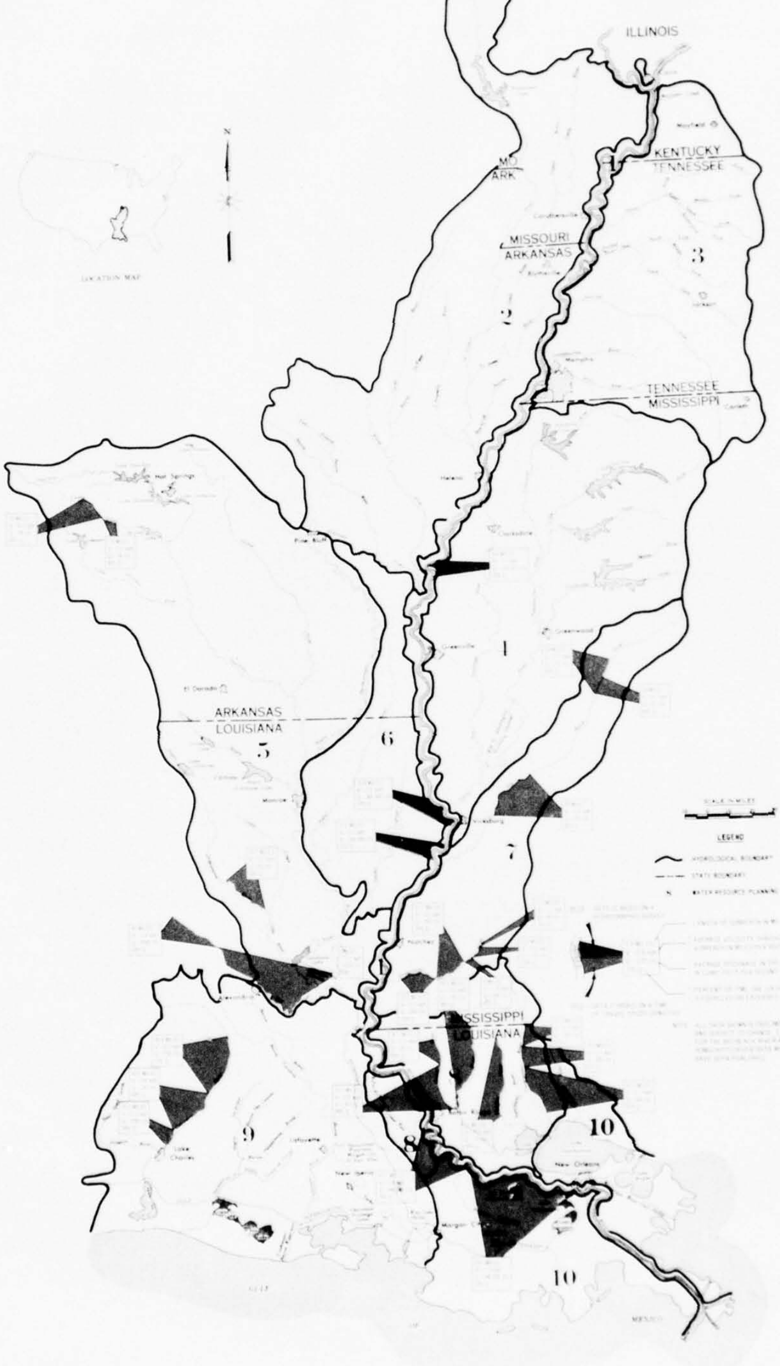
Flow Velocities

Information concerning the rate at which water passes through a reach of a stream is important in determining the capacity of the stream to assimilate waste. This information is essential to water resources planners and industrial developers who are responsible for the economic use of the water in the stream and to agencies concerned with the safeguarding of the well-being of the public. The flow velocity data are important in regard to both domestic and industrial pollution, thermal pollution, and water quality factors related to pesticides, dissolved oxygen content, and sediment transport.

Time of travel studies have been made in WRPA's 1, 5, 7, 8, and 9 on a total of eleven streams in the region. Travel times were determined by timing the maximum concentration of a dye injection as it moved downstream through a specific subreach of a stream at flows which were equaled or exceeded 50 to 99 percent of the time. These travel time studies were used to compute the average velocity in the subreach of the stream for intermediate and low flow conditions. In WRPA 1, hydrographic surveys were used on the Mississippi River near Rosedale and Vicksburg, Miss., to determine the average velocities. A summary of the data derived from the time of travel studies is shown in figure 53. The approximate reach of stream for which the study was made, the length of the reach, the velocity of flow in miles per hour, the average flow in the subreach at the time of study, and the duration of flow are presented in the figure. The velocities shown in figure 53 are for a specific discharge, and since velocity varies with discharge, the user should be cautious in applying these data to any other condition of flow. The velocities represent the average velocity through a subreach; however, velocities can vary from point to point within a subreach. The velocities given for WRPA's 1, 5, 8, and 9 were derived from preliminary studies and are subject to revision, whereas those for WRPA 7 were obtained from published reports [74]. No low flow velocity data were available for streams in any of the other WRPA's.

River Profiles

River profiles of selected streams in the Lower Mississippi Region are presented in the WRPA sections. These profiles were constructed



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

LOW FLOW VELOCITIES OF STREAMS

FIGURE 53

from topographic maps and data from available reports [101, 136, 138]. On most of the profiles, the 50 percent duration flow line was plotted from duration data at various stations along the streams. Profiles of regulated streams also show the navigation locks and dams and their respective pool stages.

Water Quality

Introduction

Large quantities of surface water of good quality are available regionally; however, significant water quality problems exist in some places in the region. The dissolved-solids concentration of water from most streams generally is less than 500 mg/1 (milligrams per liter), and only three streams sampled contained dissolved solids greater than 1,000 mg/1.

The extent of salt-water intrusion in all streams discharging into the Gulf of Mexico has not been precisely determined; however, measurements on the Mississippi River since 1929 show that the maximum extent of salt-water intrusion occurred in October 1939. The intrusion extended 120 river miles from the Gulf to a point approximately 15 miles upstream from New Orleans, La. During this period the river discharge was low, ranging from 75,000 to 90,000 c.f.s. for 30 consecutive days.

Water temperatures of the Mississippi River near St. Francisville, La., range from 34° to 88° F. Since 1954, the temperature was equal to or less than 82° F 95 percent of the time, and equal to or less than 64° F 50 percent of the time.

Water in streams during periods of low flow is mainly ground water discharge. Consequently, the chemical quality of surface water at low flow is similar to the chemical quality of the ground water. The chemical characteristics of this water are related to the chemical composition and solubility of the rocks in the drainage basins and the length of time that the water has been in contact with the rocks.

Use and reuse of water for irrigation in some areas has resulted in a general downstream increase in the dissolved-solids concentration of some streams. Deterioration of the chemical quality of surface water supplies occurs in and around major industrial and municipal complexes.

Sediment is a water quality problem in many parts of the region and adversely affects uses of water for municipal, industrial, agricultural, fishery, recreational, and aesthetic uses. Additional information on water quality and sediment and erosion can be obtained in Appendix L and Appendix S, respectively.

Temperature

Streams of the Lower Mississippi Region exhibit a characteristic seasonal curve following closely the mean air temperature seasonal variation, with the highest mean monthly water temperature of 80° to 85° F usually in August, and the lowest means of 40° to 58° F occurring in January. For the region near the Gulf, mean temperature may be slightly higher, and, for the northern part of the region, slightly lower than those stated. Figure 54 shows ranges in water temperature in selected streams. In general, summer water temperatures on small streams, sift streams, and those shaded by vegetation and woods, will be lower than the temperatures which prevail on the larger, slower flowing streams well exposed on the valley floor. Much of a stream temperature gain is caused by solar radiation, and high values of turbidity cause this heat gain to be localized in the near-surface layers. In slow moving or stagnant streams, these high temperatures stimulate the growth of taste- and odor-producing organisms which compound water use problems.

Drastically changed temperatures in streams below newly installed dams can be a considerable problem for fish and water oriented wildlife managers. To compensate for this, some method of temperature control for outflows must be planned in the design stage, such as multilevel ported intake towers on outlet conduits which allow a mixing in order to obtain beneficial temperatures in the channels and streams below the outlet works.

Cold water temperatures are seldom a problem, especially in the lower part of the region where below freezing temperatures are of such short duration that flowing streams rarely are frozen. Below Cairo, Ill., ice floes from the upper rivers impede river traffic only infrequently.

Sedimentation

The rate of erosion and the amount of sediment carried by streams have been influenced by changes in land use and agricultural practices in the Lower Mississippi Region. The rate of sedimentation can be controlled and decreased to a certain extent by the use of wise land and water management practices, but can never be eliminated.

The overall problem of sedimentation in the Lower Mississippi Region is a closely related derivative of the problems of land surface erosion, channel bank erosion, and channel scouring. The problem of land surface erosion is considered to be a land-resources related problem and is discussed in further detail in Appendix S, Sediment and Erosion. Problems relating to sediment transported by streams and sediment in reservoirs are discussed in the following topics.

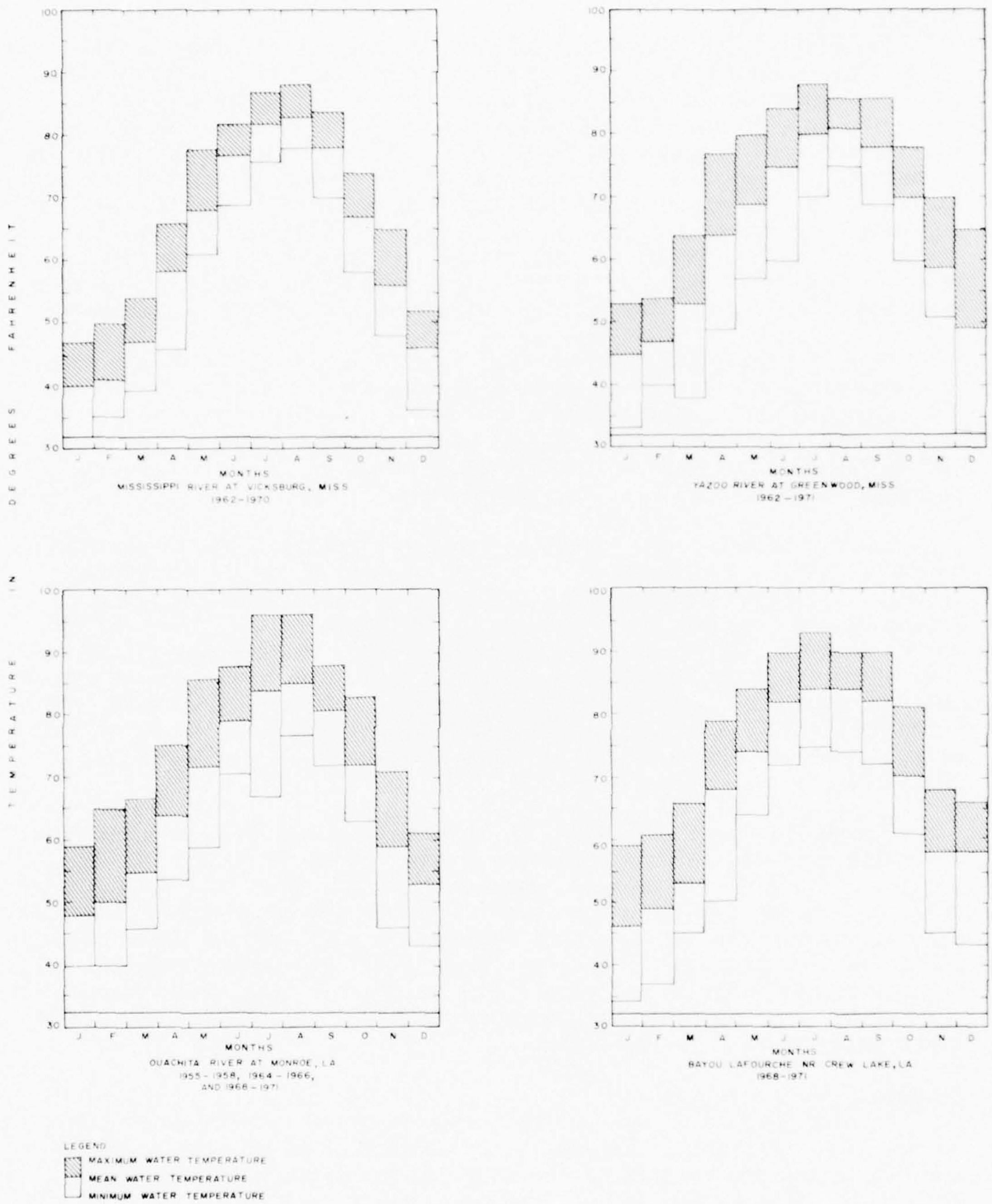


Figure 54. Ranges in Temperature of Water in Selected Streams for Periods Indicated

Sediment in Streams

Sediment is transported in streams as suspended load or as bed load. The suspended load is composed of very fine clay, silt, or sand particles which are held in suspension by colloidal suspension or by the turbulence of the flowing water. The coarser particles may also be carried along as suspended material or may be moved along the bottom and transported as bed load. The bed load of the stream is composed of particles which are removed from the streambed by the friction of the flowing water and are rolled or skipped downstream along the bottom of the stream. The size, shape, and density of the streambed material, stream velocity and turbulence, and water temperature are factors which determine the amount of bed load which a stream may be capable of carrying.

Flow conditions in a stream have a significant effect on the amount or concentration of sediment carried by the stream. During periods of low flow, sediment concentrations are usually low and change little from day to day. However, during periods when streamflows are increased by the addition of surface runoff containing newly eroded material, the sediment concentration may increase rapidly.

One of the major sedimentation problems in the region is the formation of bars or "crossings" on the Mississippi River, which often results in impeded river traffic. These "crossings" occur where the stream current crosses from one side of the river to the other and deposits sand to form the bars. The depth at the crossing determines the navigation depth available on the river. These crossings are dredged in order to maintain a 9-foot navigation channel between Cairo, Ill., and Baton Rouge, La. The required dredging in this reach of the river usually ranges from about 30 million to 70 million cubic yards per year [132].

Due to the large variations in sediment concentration and bed load, the collection of sediment data over a long period of record is often required to define the average annual sediment yield from a basin. However, data covering only a few years of record are often useful in predicting a value for the long-term sediment yield in basins where sedimentation is a problem. Shown in tables 16 through 20 are sediment data which were available for stations along the Mississippi, Atchafalaya, and Red Rivers. No sediment data were readily available for any of the other major streams in the region.

Reservoir Sedimentation

A major purpose of many of the major reservoirs or man-made lakes in the Lower Mississippi Region is the storage of flood waters during the wet season and release of the water during critical dry periods. When a lake is constructed to store the water of a flowing stream, the immediate destruction of its storage capacity by means of sediment deposition begins. As the muddy waters of the flowing stream enter the reservoir and the velocity decreases, the sediment-carrying capacity of the

Table 16 - Summary of Measured Suspended Sediment Loads at Main River Stations Lower Mississippi River at Baton Rouge and Red River Landing, Louisiana 1/

Water Year (October-September)	Total Measured Sediment Load (in 1,000 tons)	Sand-Silt Ratio				Water Year Discharge (1,000 dsf)	Average Sediment Concentration (in ppm)
		Sand (in 1,000 tons)	Per-cent	Silt (in 1,000 tons)	Per-cent		
1949-50	548,330	107,770	20	440,560	80	245,200	828
1950-51	575,280	67,600	12	507,680	88	224,810	947
1951-52	408,390	73,820	18	334,570	82	200,660	754
1952-53	212,580	28,920	14	183,660	86	142,200	552
1953-54	107,730	14,090	13	93,650	87	88,660	449
1954-55	211,490	39,930	19	171,550	81	137,460	570
1955-56	161,220	25,920	16	135,300	84	127,530	468
1956-57	291,388	53,043	18	238,345	82	172,875	624
1957-58	325,774	95,203	29	230,571	71	195,653	616
1958-59	230,504	78,693	34	151,811	66	129,253	660
1959-60	318,234	77,219	24	241,015	76	163,856	718
1960-61	231,754	71,471	31	160,283	69	168,133	510
1961-62	264,031	94,037	36	169,994	64	191,007	512
1962-63	100,397	23,770	24	76,627	76	105,125	353
1963-64	125,189	17,836	14	107,353	86	122,965	377
1964-65	201,653	43,683	22	157,970	78	150,152	497
1965-66	148,341	38,159	26	110,182	74	123,918	443
1966-67	112,283	16,986	15	95,297	85	131,861	336
1967-68	158,132	39,490	25	119,642	75	162,971	362
1968-69	165,527	38,959	24	126,568	76	167,999	365
1969-70	149,408	49,979	33	99,429	67	151,448	365
Averages	240,364	52,218	22	188,193	78	157,321	538

Note: The sand fraction is the material retained on the No. 230 sieve (0.062 mm). The silt fraction includes all of the fine material passing the No. 230 sieve.

1/ Sampling at Red River Landing after 1 January 1958, and Tarbert's Landing after 1 October 1963.

Table 17 - Summary of Measured Suspended Sediment Loads at Main River Stations Atchafalaya River at Simmesport, Louisiana

Water Year (October-September)	Total Measured Sediment Load (in 1,000 tons)	Sand-Silt Ratio				Water Year Discharge (1,000 dsf)	Average Sediment Concentration (in ppm)
		Sand (in 1,000 tons)	Per-cent	Silt (in 1,000 tons)	Per-cent		
1951-52	196,460	48,890	25	147,570	75	80,800	900
1952-53	135,230	28,440	21	106,790	79	56,960	880
1953-54	54,130	13,110	24	41,020	76	31,980	627
1954-55	93,360	24,080	26	69,280	74	50,425	686
1955-56	67,175	15,540	23	51,730	77	49,080	507
1956-57	225,474	55,700	25	169,774	75	74,059	1,126
1957-58	214,390	48,082	22	166,308	78	89,413	887
1958-59	83,230	20,944	25	62,286	75	55,729	553
1959-60	131,878	24,153	18	107,725	82	69,333	704
1960-61	133,372	40,524	30	92,848	70	76,814	643
1961-62	151,913	57,675	38	94,238	62	88,881	633
1962-63	44,876	8,610	19	36,266	81	47,060	353
1963-64	58,132	11,358	20	46,774	80	33,112	650
1964-65	109,971	28,777	26	81,194	74	66,448	619
1965-66	83,689	19,554	23	64,134	77	51,024	607
1966-67	54,451	7,195	13	47,255	87	57,327	352
1967-68	110,513	19,566	18	90,947	82	80,176	510
1968-69	119,904	27,444	23	92,460	77	83,292	533
1969-70	76,883	20,606	27	56,276	73	74,559	382
Averages	112,896	27,381	24	85,520	76	64,025	640

Table 18 - Summary of Measured Suspended Sediment Loads at Main River Stations Red River at Alexandria, Louisiana

Water Year (October-September)	Total Measured Sediment Load (in 1,000 tons)	Sand-Silt Ratio				Water Year Discharge (1,000 dsf)	Average Sediment Concentration (in ppm)
		Sand (in 1,000 tons)	Per-cent	Silt (in 1,000 tons)	Per-cent		
1951-52	39,560	6,450	16	33,110	84	8,460	1,730
1952-53	43,760	11,900	27	31,860	73	12,550	1,290
1953-54	16,490	3,130	19	13,360	81	5,910	1,030
1954-55	21,830	3,590	16	18,240	84	7,340	1,102
1955-56	13,400	2,210	17	11,190	83	4,380	1,132
1956-57	82,385	16,950	21	65,432	79	16,779	1,817
1957-58	95,623	15,279	16	80,344	84	18,473	1,915
1958-59	13,565	4,164	31	9,401	69	6,832	735
1959-60	31,939	6,231	20	25,708	80	9,821	1,204
1960-61	46,957	12,199	26	34,758	74	12,735	1,365
1961-62	45,582	10,906	24	34,676	76	12,515	1,349
1962-63	9,818	2,574	26	7,244	74	4,992	728
1963-64	11,445	1,930	17	9,516	83	4,201	1,008
1964-65	20,620	3,939	19	16,681	81	6,856	1,818
1965-66	32,063	6,805	21	25,257	79	8,048	1,476
1966-67	15,378	2,654	17	12,724	83	6,795	838
1967-68	70,312	20,990	30	49,322	70	16,184	1,608
1968-69	59,887	16,654	28	43,234	72	14,815	1,497
1969-70	32,354	7,834	24	24,520	76	8,693	1,377
Average	36,998	8,230	22	28,767	78	9,809	1,317

Table 19 - Summary of Measured Suspended Sediment Loads in Atchafalaya Basin Outlets Wax Lake Outlet at Calumet, Louisiana

Water Year (October-September)	Total Measured Sediment Load (in 1,000 tons)	Sand-Silt Ratio				Water Year Discharge (1,000 dsf)	Average Sediment Concentration (in ppm)
		Sand (in 1,000 tons)	Per-cent	Silt (in 1,000 tons)	Per-cent		
1965-66	12,477	539	4	11,938	96	15,307	302
1966-67	11,851	633	5	11,218	95	17,194	255
1967-68	22,571	1,779	8	20,792	92	24,048	348
1968-69	22,892	2,016	9	20,876	91	24,984	339
1969-70	15,651	1,162	7	14,489	93	22,113	262
Average	17,088	1,226	7	15,863	93	20,729	301

Table 20 - Summary of Measured Suspended Sediment Loads in Atchafalaya Basin Outlets Lower Atchafalaya River at Morgan City, Louisiana

Water Year (October-September)	Total Measured Sediment Load (in 1,000 tons)	Sand-Silt Ratio				Water Year Discharge (1,000 dsf)	Average Sediment Concentration (in ppm)
		Sand (in 1,000 tons)	Per-cent	Silt (in 1,000 tons)	Per-cent		
1965-66	32,442	1,080	3	31,362	97	35,716	336
1966-67	29,625	905	3	28,720	97	40,119	273
1967-68	63,076	4,339	7	58,737	93	56,072	417
1968-69	61,958	5,750	9	56,208	91	58,331	393
1969-70	44,942	5,161	11	39,781	89	52,000	320
Average	46,409	3,447	7	42,962	93	48,448	348

water decreases, and the sediment begins to settle to the bottom of the lake. A continual accumulation of the sediment deposits tends to decrease the capacity of the lake for storing water. The sediment continues to distribute itself evenly throughout the lakebed and, therefore, is not visible from the surface of the lake. Hence, much of the capacity of the lake for storing water can be lost to sediment accumulation although no problems may seem to be apparent. For this reason, the need for frequent reservoir sedimentation surveys is apparent.

Table 21 shows current data on the sediment studies made on four flood-control lakes in WRPA 4. These studies were made to determine the degree of storage capacity lost due to sediment deposition in the lakes. Additional data for other lakes in the region were not readily available for publication in this appendix.

Table 21 - Sedimentation Data for Selected Reservoirs in Lower Mississippi Region

Item	Lake			
	Arkabutla	Sardis	Enid	Grenada
Drainage area (square miles)	1,000	1,545	560	1,320
Drainage area excluding reservoir (square miles)	948	1,454	516	1,219
Total sediment deposited (acre-feet)	12,238	20,564	2,829	17,377
Total years of operation 1/	21	21	10	12
Estimated 50-year sediment deposition (acre-feet)	29,500	50,000	5,400	73,450
Volume of sediment per year (acre-feet)	590	998	287	1,470
Volume of sediment per year per square mile (acre-feet)	0.62	0.69	0.56	1.21
Percent of total storage lost	2.33	1.31	0.43	1.30

1/ At time of study (1966).

GEOLOGY AND GROUND WATER

Geology

The geologic units exposed in the Lower Mississippi Region range in age from Precambrian to Holocene; however, most of the region is blanketed by Quaternary deposits. Immediately underlying the Quaternary deposits in the northern part of the region are scattered subcrops of rocks of Paleozoic age and limited areas of Cretaceous sediments; elsewhere, the underlying sediments are of Tertiary age (figure 55).

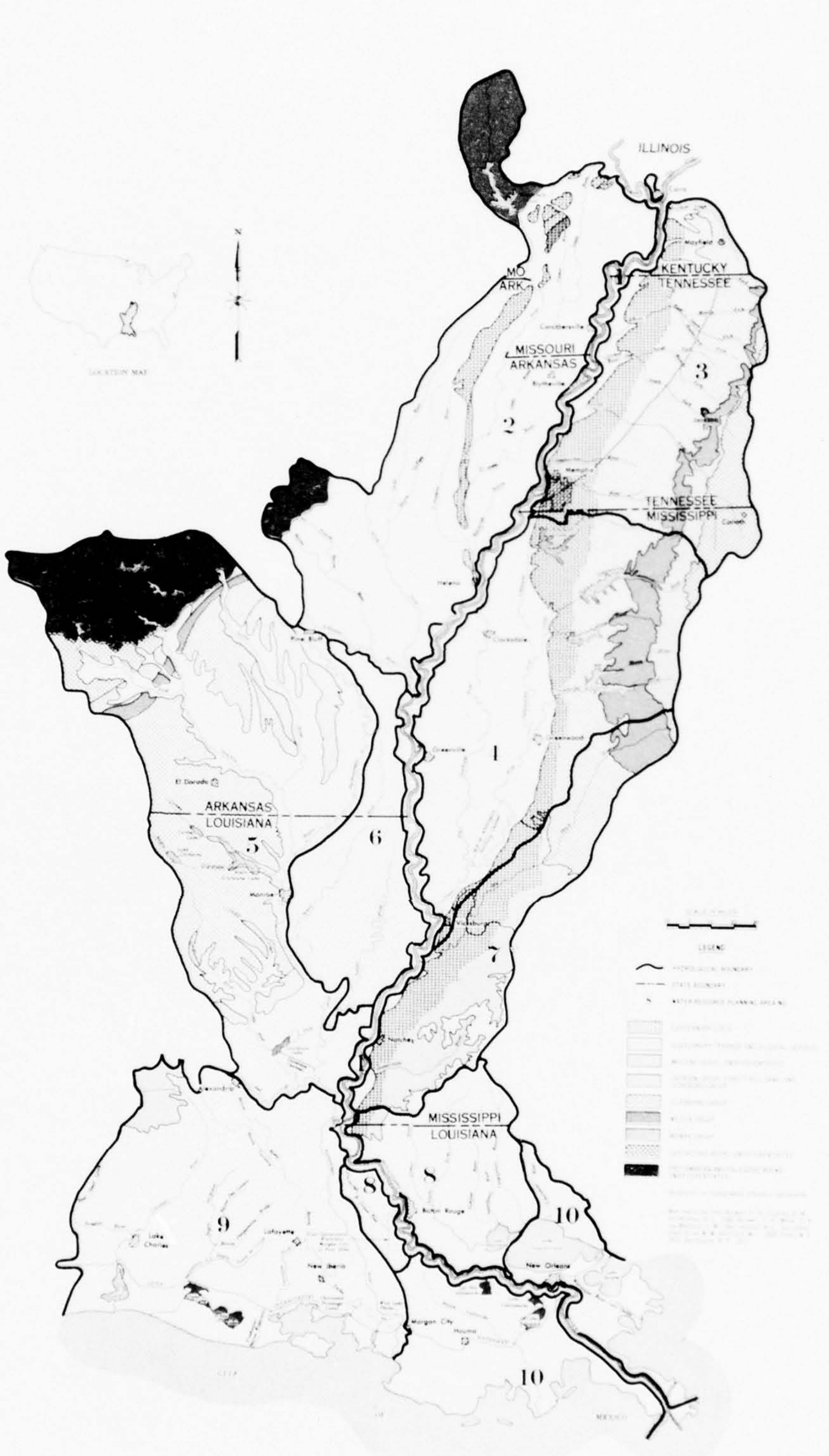
In the northern part of the region, the dip of the beds generally is toward the axis of the Mississippi embayment syncline. In the central part of the region, the direction of dip of the beds changes gradually as a result of the regional structure, and in southern Mississippi and Louisiana the dip is toward the axis of the Gulf Coast geosyncline (figure 56). Structural features such as the Monroe uplift and Jackson dome have affected the dip, thickness, and physical character of the beds. Generally, the beds thicken down the dip and attain their maximum thickness in the areas of greatest subsidence. The stratigraphic and structural relations of the geologic units are shown in figure 57 and table 22.

Sediments of Jurassic age, which occur only in the subsurface of the southern part of the region, are the oldest known post-Paleozoic rocks in the region. As subsidence continued, sediments of Cretaceous age were deposited successively farther north to a point above the present confluence of the Mississippi and Ohio Rivers. During the Tertiary and Quaternary Periods, subsidence in the area that had become the Mississippi embayment diminished, subsidence of the Gulf Coast geosyncline began, and the cyclic advances of the sea terminated progressively farther southward. The last major advance of the sea into the northern part of the Mississippi embayment probably occurred during the late Eocene.

Since the beginning of the Miocene, tremendous quantities of sediments have been deposited in the subsiding Gulf Coast geosyncline. During Pleistocene and Holocene time, the Mississippi River Valley was entrenched and alluviated. The Quaternary deposits now filling the Mississippi River Valley are underlain by the subcrop of the older rocks. On the west side of the valley, Paleozoic rocks and sediments of Cretaceous age underlie the Quaternary deposits near the periphery of the Coastal Plain. Elsewhere, the Quaternary deposits are underlain mostly by Paleocene, Eocene, and Miocene rocks.

Precambrian and Paleozoic Rocks

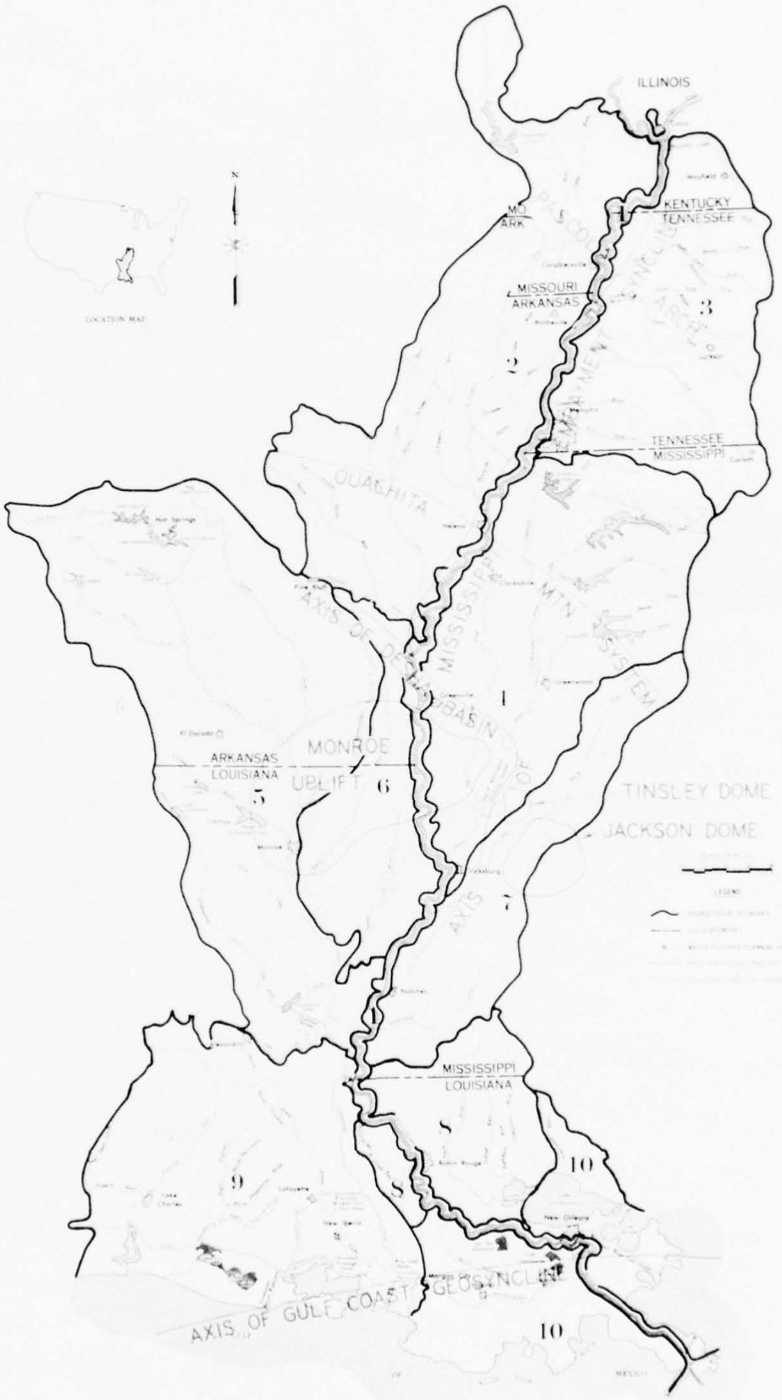
The Mississippi embayment of the Gulf Coastal Plain was formed in a subsiding trough in the rocks of Paleozoic age which now bound the



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOLOGIC MAP

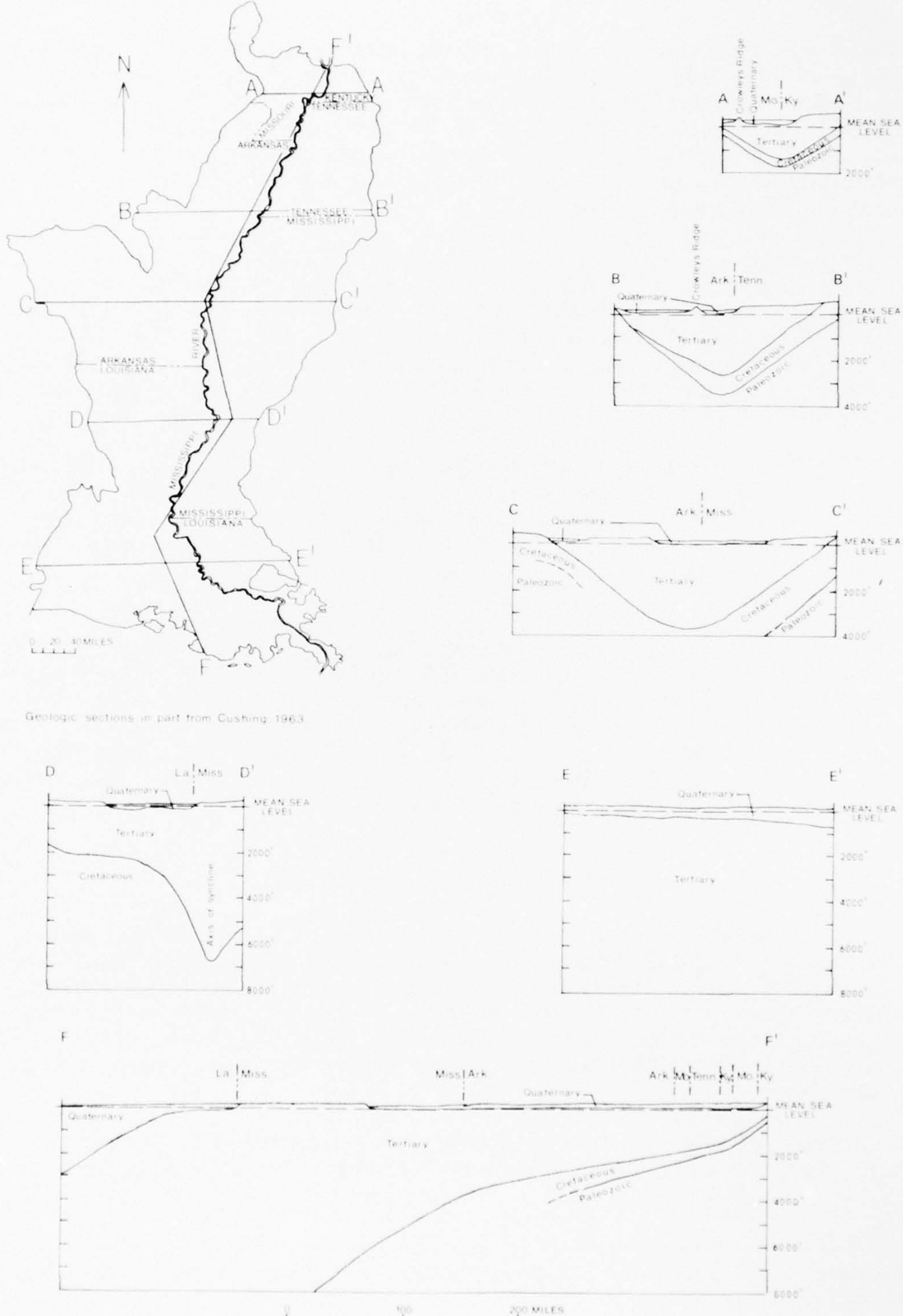
FIGURE 55



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

STRUCTURAL MAP OF THE LOWER MISSISSIPPI REGION

FIGURE 56



Geologic sections in part from Cushing 1963

Figure 57 GENERALIZED GEOLOGIC SECTIONS IN THE LOWER MISSISSIPPI REGION

coastal plain at the fall line. In the area included in this report, Paleozoic rocks are exposed only in Arkansas and Missouri; however, these rocks are the "basement rocks" underlying the northern part of the region (figure 55). In the parts of Arkansas and Missouri that are outside the Gulf Coastal Plain, the exposed rocks range from Cambrian to Pennsylvanian in age. Precambrian rocks are exposed in the St. Francois Mountains in Missouri [159].

Mesozoic Rocks

The oldest known Mesozoic rocks occur in the subsurface of the Lower Mississippi River Region, are of Jurassic age, and underlie southern Arkansas, central and southern Mississippi, and Louisiana. Overlying the Jurassic rocks and extending somewhat farther north are rocks of the Lower Cretaceous Series. Lower Cretaceous rocks are exposed only in Pike County, Ark.

The Upper Cretaceous Series underlies most of the region. Although there are extensive exposures of Upper Cretaceous rocks in the Mississippi embayment, exposures in the study area are restricted to a few counties near the boundaries of the area in Arkansas, Mississippi, Missouri, and Tennessee.

Cenozoic Rocks

Most of the sediments now exposed in the Lower Mississippi Region were deposited during the Tertiary and Quaternary Periods. The Tertiary Period was characterized by repeated invasions and regressions by the sea and the sediments are on alternating series of sand and clay strata of continental, deltaic, and marine origin. Tertiary rocks comprise the Paleocene, Eocene, Oligocene, Miocene, and Pliocene Series. The most extensive deposits belong to the Eocene and Miocene Series.

Occurrence of Ground Water

Fresh ground water in the Lower Mississippi Region occurs principally in the unconsolidated sediments composing the Cretaceous, Tertiary, and Quaternary units; however, water is available from Paleozoic aquifers where they are exposed or underlie younger rocks in the northern part of the region. In those parts of the study region outside the Gulf Coastal Plain, the Paleozoic aquifers are the principal source of ground water.

Large volumes of fresh 1/ ground water are stored in permeable rocks underlying the Lower Mississippi Region. The average volume in

---

1/ Water containing less than 1,000 mg/l of dissolved solids is classified as fresh.

Table 22 - Correlation Chart

ERA	SYSTEM	SERIES	LOUISIANA	ARKANSAS	MISSOURI	ILLINOIS	KENTUCKY	TENNESSEE	MISSISSIPPI
		HOLOCENE AND PLEISTOCENE	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial depo undifferent
	QUATERNARY	PLEISTOCENE AND PLIOCENE	Loess Terrace deposits, undifferentiated Citronelle Formation	Loess Terrace deposits, undifferentiated	Loess Terrace deposits, undifferentiated	Loess Terrace deposits, undifferentiated	Loess Terrace deposits, undifferentiated Pliocene(?) gravel	Loess Terrace deposits, undifferentiated	Loess Terrace depo undifferent Citronelle Fo
		MIOCENE	Fleming Formation[1] Catahoula Formation						Pascagoula Fo Fort Adams Homochitto Hattiesburg F Catahoula San
		OLIGOCENE	Vicksburg Formation						Vicksburg Group Byram Formati Bucatunna C Middle marl Glendon Lim Marianna Lime Mint Spring Forest Hill S
CENOZOIC	TERTIARY	EOCENE	Jackson Group Yazoo Clay Moodys Branch Formation	Jackson Group Undifferentiated					Jackson Group Yazoo Clay Member Moodys Branch
			Claiborne Group Cockfield Formation Cook Mountain Formation Sparta Sand Cane River Formation Carrizo Sand	Claiborne Group Cockfield Formation Cook Mountain Formation Sparta Sand Cane River Formation Carrizo Sand	Claiborne Group Undifferentiated		Claiborne Group Cockfield through Jackson Formations, undivided Cook Mountain Formation Sparta Sand Tallahatta Formation	Claiborne Group Jackson, Cockfield, and Cook Mountain Formations, undifferentiated Memphis Sand	Claiborne Group Cockfield Fo Cook Mountai Sparta Sand Zilpha Clay Winona Sand Tallahatta Fo Neshoba Sa Basic City Meridian S
			Wilcox Group Undifferentiated[2]	Wilcox Group Undifferentiated	Wilcox Formation	Wilcox Group Undifferentiated	Wilcox Formation	Wilcox Group Flour Island Formation Fort Pillow Sand Old Breastworks Formation	Wilcox Group Undifferenti
		PALEOCENE	Dolet Hills Formation Naborton Formation Midway Group Porters Creek Clay	Midway Group Porters Creek Clay Clayton Formation	Midway Group Porters Creek Clay Clayton Formation	Midway Group Porters Creek Clay Clayton Formation	Midway Group Porters Creek Clay Clayton Formation	Midway Group Porters Creek Clay Clayton Formation	Naheola For Midway Group Porters Cre Tippah Sa Clayton Fo
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	Arkadelphia Marl Nacatoch Sand Saratoga Clay Marlbrook Marl Annona Chalk Brownstown Marl Tokio Formation Eagle Ford Shale Woodbine Formation	Arkadelphia Marl Nacatoch Sand Marlbrook Marl Annona Chalk Ozan Formation Brownstown Marl Tokio Formation Woodbine Formation	Owl Creek Formation McNairy Sand	McNairy Sand	McNairy Sand Tuscaloosa Formation	Owl Creek Formation McNairy Sand Coon Creek Formation Demopolis Formation Coffee Sand Eutaw Formation Tuscaloosa Formation	Selma Group Owl Creek Ripley For Chiwapa McNairy Coon Cre Transiti Demopolis Coffee Sand Eutaw For Tombigb McShan Fo Tuscaloosa Group Undiffere- ntiated
		LOWER CRETACEOUS	Undifferentiated	Undifferentiated					Undifferen
		PALEOZOIC	Undifferentiated	Undifferentiated	Undifferentiated	Undifferentiated	Undifferentiated	Undifferentiated	Undifferen

[1] In central Louisiana only.

[2] Wilcox Group (Eocene Series), undifferentiated. Wilcox Group (Paleocene Series), upper part undifferentiated; Dolet Hills and Naborton Formations are lower two units.

Table 22 - Correlation Chart

ERA	SYSTEM	SERIES	LOUISIANA	ARKANSAS	MISSOURI	ILLINOIS	KENTUCKY	TENNESSEE	MISSISSIPPI
	QUATERNARY	HOLOCENE AND PLEISTOCENE	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated	Alluvial deposits, undifferentiated
		PLEISTOCENE AND PLIOCENE	Loess Terrace deposits, undifferentiated Citronelle Formation	Loess Terrace deposits, undifferentiated	Loess Terrace deposits, undifferentiated	Loess Terrace deposits, undifferentiated	Loess Terrace deposits, undifferentiated Pliocene(?) gravel	Loess Terrace deposits, undifferentiated	Loess Terrace deposits, undifferentiated Citronelle Formation
CENOZOIC	TERTIARY	MIOCENE	Fleming Formation[1] Catahoula Formation						Pascagoula Formation Fort Adams Member Homochitto Member Hattiesburg Formation Catahoula Sandstone
		OLIGOCENE	Vicksburg Formation						Vicksburg Group: Byram Formation Bucatunna Clay Member Middle marl member Glendon Limestone Member Marianna Limestone Mint Spring Marl Member Forest Hill Sand
		EOCENE	Jackson Group: Yazoo Clay Moodys Branch Formation	Jackson Group: Undifferentiated					Jackson Group: Yazoo Clay Shubuta Member Pachuta Marl Member Cocoa Sand Member North Twistwood Creek Member Moodys Branch Formation
			Claiborne Group: Cockfield Formation Cook Mountain Formation Sparta Sand Cane River Formation Carrizo Sand	Claiborne Group: Cockfield Formation Cook Mountain Formation Sparta Sand Cane River Formation Carrizo Sand	Claiborne Group: Undifferentiated		Claiborne Group: Cockfield through Jackson Formation, undivided Cook Mountain Formation Sparta Sand Tallahatta Formation	Claiborne Group: Jackson, Cockfield, and Cook Mountain Formations, undifferentiated Memphis Sand	Claiborne Group: Cockfield Formation Cook Mountain Formation Sparta Sand Zilpha Clay Winona Sand Tallahatta Formation Neshoba Sand Member Basic City Shale Member Meridian Sand Member
			Wilcox Group: Undifferentiated[2]	Wilcox Group: Undifferentiated	Wilcox Formation	Wilcox Group: Undifferentiated	Wilcox Formation	Wilcox Group: Flour Island Formation Fort Pillow Sand Old Breastworks Formation	Wilcox Group: Undifferentiated
		PALEOCENE	Wilcox Group: Dolet Hills Formation Naborton Formation Midway Group: Porters Creek Clay	Midway Group: Porters Creek Clay Clayton Formation	Midway Group: Porters Creek Clay Clayton Formation	Midway Group: Porters Creek Clay Clayton Formation	Midway Group: Porters Creek Clay Clayton Formation	Midway Group: Porters Creek Clay Clayton Formation	Naheola Formation Midway Group: Porters Creek Clay Tippah Sand Lentil Clayton Formation
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	Arkadelphia Marl Nacatoch Sand Saratoga Clay Marlbrook Marl Annona Chalk Brownstown Marl Tokio Formation Eagle Ford Shale Woodbine Formation	Arkadelphia Marl Nacatoch Sand Marlbrook Marl Annona Chalk Ozan Formation Brownstown Marl Tokio Formation Woodbine Formation	Owl Creek Formation McNairy Sand	McNairy Sand	McNairy Sand Tuscaloosa Formation	Owl Creek Formation McNairy Sand Coon Creek Formation Demopolis Formation Coffee Sand Eutaw Formation Tuscaloosa Formation	Selma Group: Owl Creek Formation Ripley Formation Chiwapa Member McNairy Sand Member Coon Creek Tongue Transitional clay Demopolis Chalk Coffee Sand / MONROE COUNTY: Mooreville Chalk, Arcola Limestone Member Eutaw Formation Tombigbee Sand Member McShan Formation Tuscaloosa Group: Undifferentiated / MONROE COUNTY: Gordo Formation, Coker Formation, Massive Sand
		LOWER CRETACEOUS	Undifferentiated	Undifferentiated					Undifferentiated
		PALEOZOIC	Undifferentiated	Undifferentiated	Undifferentiated	Undifferentiated	Undifferentiated	Undifferentiated	Undifferentiated

[1] In central Louisiana only.

[2] Wilcox Group (Eocene Series), undifferentiated. Wilcox Group (Paleocene Series), upper part undifferentiated; Dolet Hills and Naborton Formations are lower two units.

storage in aquifers is estimated to be about 75,000 acre-feet per square mile, or a total of about 7,500 million acre-feet, a quantity sufficient to cover the 100,000-square-mile area to a depth of about 120 feet. An even larger volume of water is stored in fine-grained sediments (clay and silt) which have high porosity but very low permeability. Only a small part of this stored water can be withdrawn using conventional methods.

Aquifers are classified as confined and unconfined aquifers. Confined (artesian) aquifers are bounded above and below by beds of lower permeability than that of the aquifer itself. Unconfined (water table) aquifers are characterized by a free water table and are not confined under pressure.

The more prolific and extensive aquifers are the permeable sand and gravel beds in the unconsolidated sediments. Water from precipitation moves into the subsurface where these beds are exposed. Except in the outcrop areas, the water is confined in these aquifers under artesian conditions. The altitude of the water table in the upland outcrop areas provides sufficient hydraulic head to move water through some of the aquifers to depths as great as 3,500 feet, thereby displacing or "flushing" the connate saline water.

The unconsolidated aquifers are irregular in thickness and lithology, exhibiting extreme variations in the capability of storing and transmitting water. Some individual aquifers underlie many thousands of square miles, and water-bearing characteristics vary according to changes in thickness and permeability. Hydraulic interconnection of aquifers is not uncommon, and groups of aquifers may form aquifer systems that are not necessarily restricted to a single geologic unit.

Consolidated rocks forming the Paleozoic aquifers are water bearing due to primary porosity or secondary porosity. Where rocks have not been subjected to extensive compaction or deformation, as in the Ozark Mountains of Missouri, ground water occurs in permeable zones and in solution openings (secondary porosity). Tectonic disturbances may result in compaction of consolidated rock to the degree that primary porosity is destroyed and ground water commonly occurs in joints and fractures, as in the Ouachita Mountains of Arkansas.

With the exception of some aquifers having solution openings, consolidated-rock aquifers are generally lower yielding than aquifers in unconsolidated rocks.

Movement of Ground Water

Ground water moves from points of recharge to points of discharge. In water table aquifers, the direction of movement is generally related

to topography. The movement in artesian aquifers, more complex, is controlled by the strike and dip of the aquifer, changes in permeability in the aquifer, and the locations of recharge and discharge areas. Generally in the Lower Mississippi Region, the deeper aquifers in a given locality crop out farther inland and at higher altitudes than do the shallower aquifers; as a result, they commonly have higher artesian heads.

In the northern part of the Lower Mississippi Region, the natural movement of ground water in the Cretaceous and Tertiary aquifers was toward the axis of the Mississippi embayment. Water moved from upland recharge areas to areas of natural discharge in the Mississippi Alluvial Plain. In Louisiana and southwestern Mississippi, the regional ground-water movement was southward toward the Gulf of Mexico. Hydraulic gradients originally were low, probably less than 2 feet per mile.

The regional movement of water in the Mississippi River Valley Alluvial aquifer was and is southward except in the vicinity of larger streams. The hydraulic gradient was probably 1 foot per mile or less, or about the same as the slope of the surface of the alluvial plain.

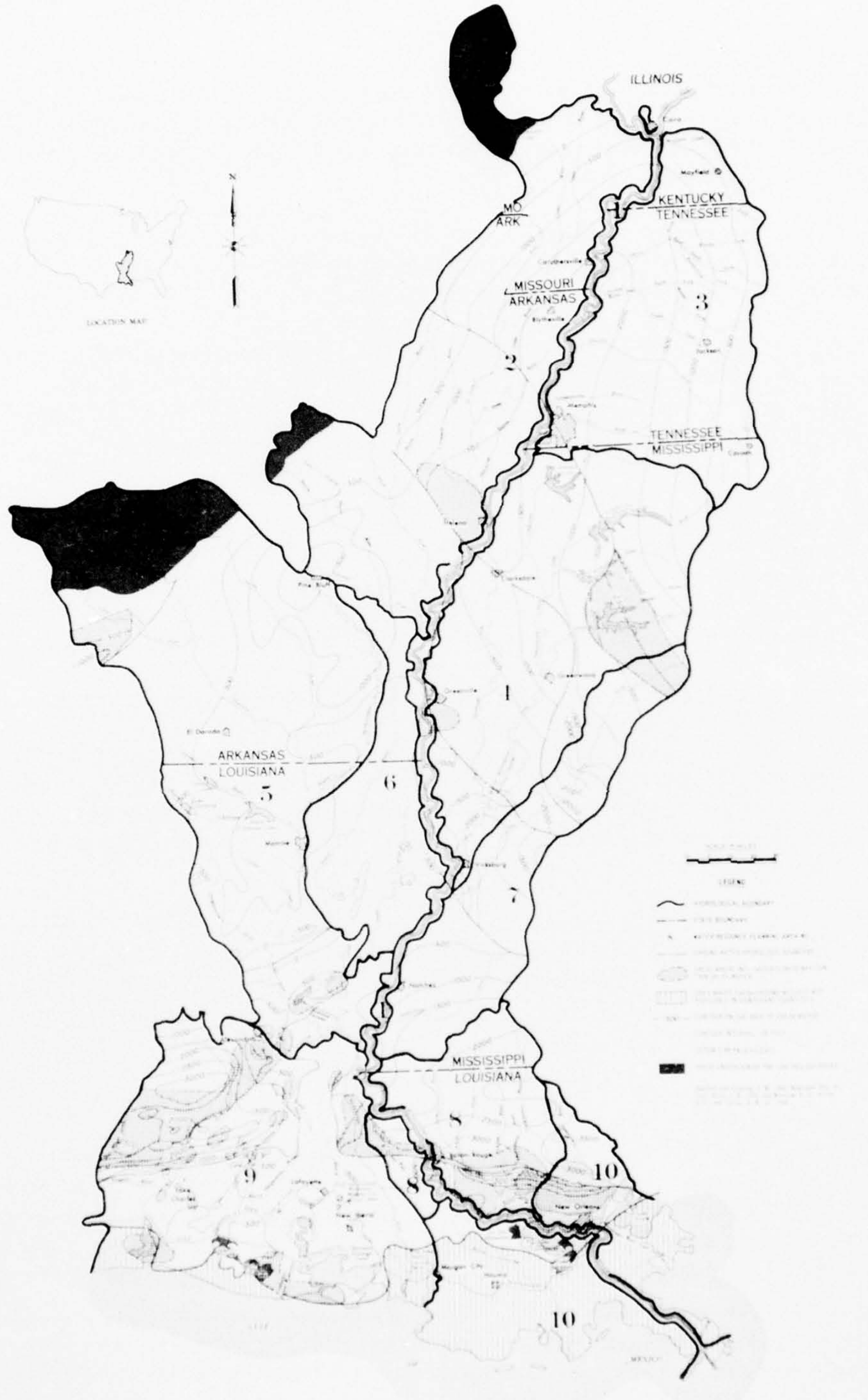
The historic direction of movement in many aquifers is now altered considerably, even reversed, in areas where large quantities of ground water are being withdrawn.

Aquifers

Aquifers in the Lower Mississippi Region are in rocks ranging in age from Cambrian to Holocene. Generally, the high yielding aquifers are in the Cretaceous and younger deposits in the Gulf Coastal Plain. Aquifers in the uplands of Arkansas and Missouri, outside the Coastal Plain, are in consolidated rocks that range in age from Precambrian to Pennsylvanian. In the Coastal Plain, water is obtained from Paleozoic rocks where they underlie Cretaceous rocks at shallow depths.

The highest yields of ground water are obtained from sand and gravel aquifers, especially the alluvial and terrace deposits of Quaternary age. Some limestone, dolomite, and chert aquifers of Paleozoic age are capable of large yields to wells; however, much of the region outside the coastal plain is underlain by low yielding sandstone and shale.

Aquifers containing fresh ground water underlie the entire region except in part of the coastal area of Louisiana and a small area in central Louisiana. In some areas, fresh water extends to depths of more than 3,000 feet and in other areas to less than 100 feet (figure 58). It is not uncommon for saline water to occur at intermediate depths, underlain by fresh-water aquifers. Two or more major aquifers underlie most localities in the region, offering a choice for meeting requirements of quantity or quality.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MAP SHOWING ALTITUDE OF THE BASE OF FRESH WATER IN COASTAL PLAIN AQUIFERS

FIGURE 58

Paleozoic Aquifers

Water-bearing Paleozoic rocks underlie those areas of the Lower Mississippi Region outside the Gulf Coastal Plain. The areas are in the Arkansas Valley and Ouachita Mountains in Arkansas, and in the Ozark Plateau in Missouri.

In the Arkansas Valley, rocks of Pennsylvanian age are capable of yielding only a few gallons per minute (gpm) to small wells. Water quality varies considerably from place to place.

Ground water in the Ouachita Mountains occurs in joints, fractures, and bedding-plane separations, principally in sandstone units. Wells commonly yield less than 10 gpm and are capable of meeting requirements for domestic and stock water.

In Missouri, that part of the Ozark Plateaus included in the Lower Mississippi Region is underlain by several aquifers in Cambrian and Ordovician rocks [159]. The only aquifer capable of large yields is the Potosi Dolomite, capable of yielding more than 1,000 gpm to large, deep wells in some localities. The Potosi generally yields good quality hard water that has a dissolved-solids content of less than 300 mg/l.

Areas where wells tap rocks of Paleozoic age that underlie Coastal Plain deposits are Jackson, Lonoke, and White Counties, Ark.; Alcorn County, Miss.; and all or part of Bollinger, Butler, Cape Girardeau, Scott, and Stoddard Counties, Mo. In Alcorn County, Miss., a chert of Paleozoic age yields about 3 mgd for municipal and industrial supplies [72]; elsewhere in the Coastal Plain, the Paleozoic aquifers are characterized by low yields.

The Paleozoic chert in Alcorn County, Miss., yields as much as 800 gpm to municipal and industrial wells at Corinth. Results of aquifer tests show coefficients of transmissibility 2/ ranging from 15,000 to 40,000 gpd per foot [71]. Water from the aquifer is a moderately hard sodium bicarbonate type containing about 300 mg/l of dissolved solids.

Cretaceous Aquifers

Aquifers of Cretaceous age underlie the northern part of the Lower Mississippi Region. Of the Cretaceous units, only the Ripley Formation and its equivalents (the McNairy Sand and Nacatoch Sand) form a major aquifer. Other cretaceous aquifers are significant because they are the best or the only sources of significant supplies of ground water in some

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2/ The U. S. Geological Survey now uses the term transmissivity as an index of the ability of an aquifer to transmit water. Transmissivity, expressed in cubic feet per day per foot, is equivalent to transmissibility divided by 7.481, the number of gallons in a cubic foot.

areas. The Cretaceous aquifers are not utilized extensively due to the availability of ground water in shallower aquifers.

The Cretaceous aquifers in the region are the Gordo and Eutaw Formations, Coffee Sand, and the Ripley Formation. The Eutaw yields highly mineralized water in part of WRPA 4 and the present trend is to develop water supplies at greater depth in the Gordo Formation, which contains fresher water.

The Gordo Formation (figure 59) is a source of ground water in the northeastern part of WRPA 4 where it is the only aquifer capable of yielding enough fresh water for public or industrial supplies. The urgent need for water has resulted in wells being drilled to depths of over 2,000 feet in Calhoun and Webster Counties, Miss. [10].

The yields of wells made in the sand and gravel of the Gordo Formation range from about 100 to 500 gpm. In the Lower Mississippi Region, transmissibilities range from low to about 14,000 gpd per foot and the average permeability 3/ is about 500 gpd per square foot.

Water from the Gordo is of fair to poor quality in the region. The dissolved-solids content ranges from 300 to 1,000 mg/l; however, the water generally does not require treatment.

The Coffee Sand (figure 59) contains fresh water in the northeastern part of WRPA 4 and the southeastern part of WRPA 3. The formation, composed of varying proportions of sand and clay, is generally a low-yielding aquifer. Permeabilities as high as 300 gpd per square foot and transmissibilities as high as 30,000 gpd per foot have been reported in Alcorn County, Miss. [72]. The largest reported yield for a well made in the aquifer is about 600 gpm, but most public water-supply wells yield about 250 gpm.

Water from the Coffee Sand generally contains iron and is a calcium bicarbonate type in and near the outcrop. As the water moves down the dip, it becomes a sodium bicarbonate type, commonly suitable for general use without treatment.

In Tippah County, Miss., and in several counties in Tennessee, the Coffee Sand is the best source of ground water. It is the only

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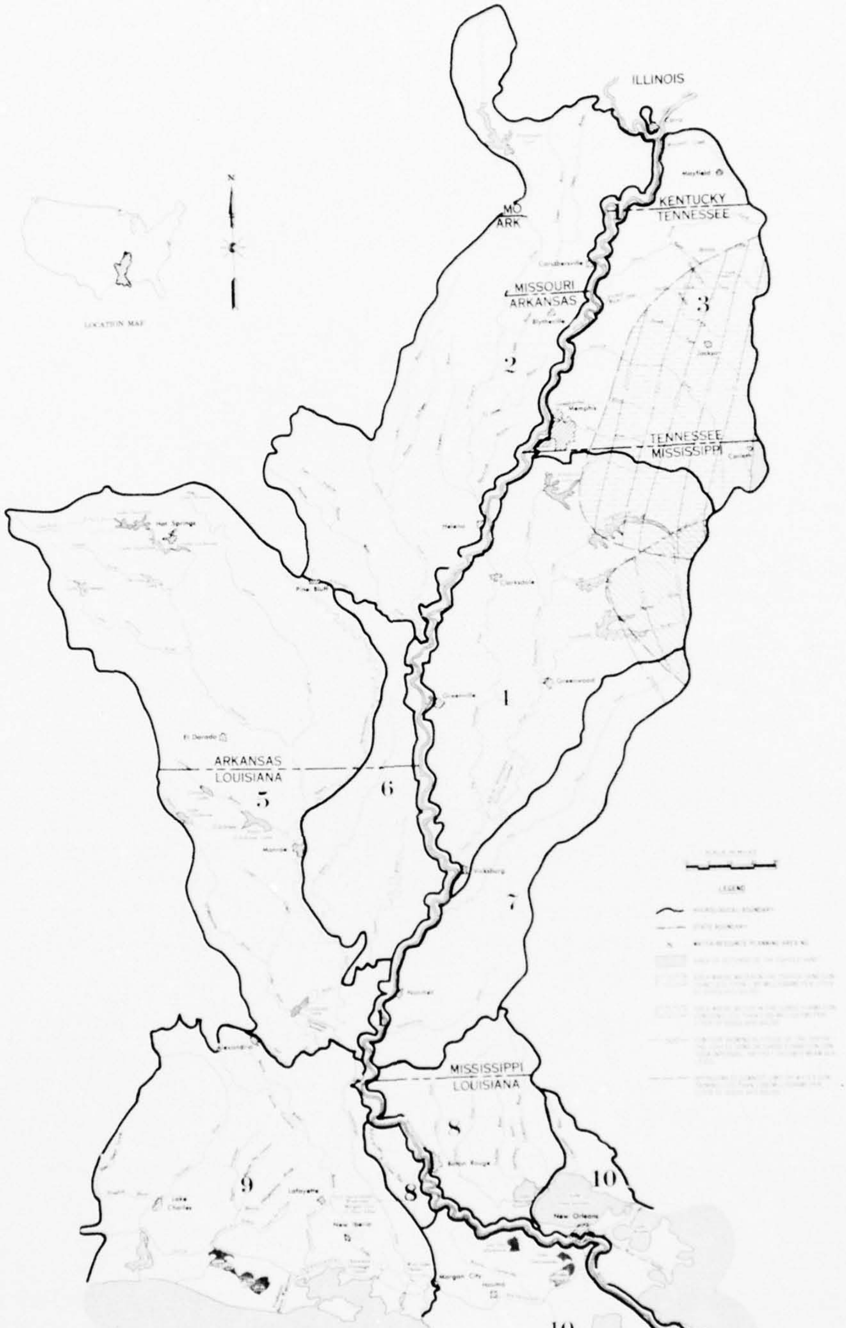
3/ Permeability has been replaced by the term hydraulic conductivity; both express the rate of flow of water through a 1-foot-square section of the aquifer under unit hydraulic gradient. Permeability is expressed in gallons per day per square foot. Hydraulic conductivity is expressed in feet per day. These parameters are obtained by dividing transmissibility or transmissivity by aquifer thickness in feet.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOHYDROLOGIC MAP OF THE COFFEE SAND AND GORDO FORMATION

FIGURE 59

significant source of ground water in some areas where the underlying Eutaw Formation is thin or where Paleozoic rocks are not aquifers.

The Ripley Formation (figure 60) and its equivalents or members, the McNairy Sand and the Nacatoch Sand, contain fresh ground water in an area of nearly 20,000 square miles. The McNairy Sand is the most extensive Cretaceous aquifer in the area. The unit crops out in Alcorn and Tippah Counties, Miss.; Carroll, Chester, and McNairy Counties, Tenn.; and immediately to the east of the study area in the remainder of the Gulf Coastal Plain in Tennessee and Kentucky. The McNairy Sand is exposed in Missouri on Crowleys Ridge and subcrops beneath the Mississippi River alluvium. The Nacatoch Sand crops out in southwestern Arkansas.

In Mississippi and Tennessee, the McNairy Sand is underlain by older units of the Ripley Formation. In Kentucky, the McNairy Sand (of formational rank) is underlain by rocks of Paleozoic age. It is overlain by the Owl Creek Formation in Mississippi, Missouri, and Tennessee.

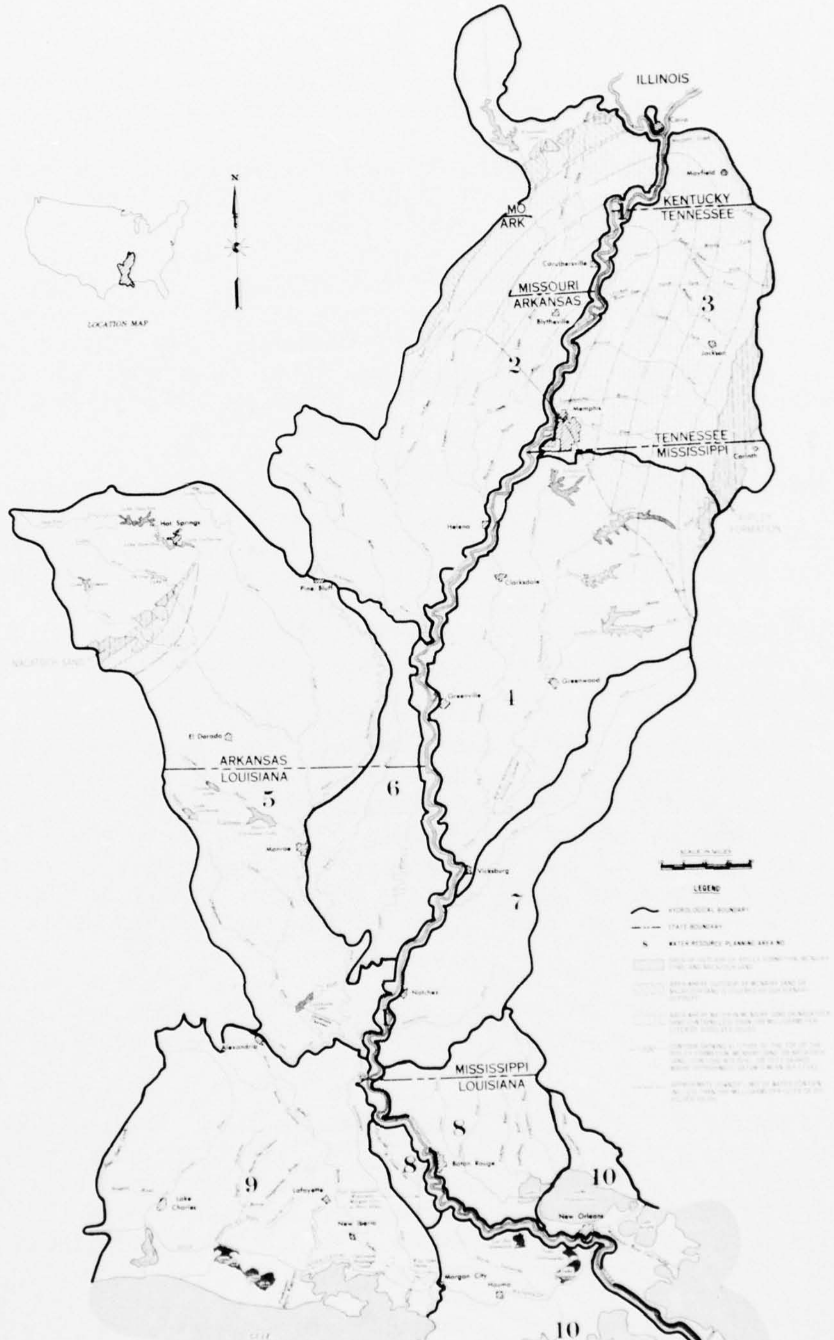
According to Pryor [86], the McNairy Sand is a deltaic unit comprising a lower sand, a medial clay, and an upper sand. The upper sand is the principal aquifer.

In the south part of WRPA 3, the McNairy Sand dips westward at a rate of about 35 feet per mile. The direction of dip gradually changes to southwest in Kentucky. Most of the present utilization of the aquifer is in or near the outcrop, and wells are seldom more than a few hundred feet in depth. The maximum depth for fresh-water wells in the aquifer ranges from about 2,000 feet in western Kentucky at the axis of the embayment syncline to about 2,300 feet in the Memphis area.

The McNairy Sand in Missouri crops out on the northern part of Crowleys Ridge. It underlies and is hydraulically connected to the Mississippi River Valley alluvial aquifer to the west and north of Crowleys Ridge.

Withdrawals from the Ripley Formation and its equivalents have generally been restricted to areas where the aquifers occur at shallow to moderate depths. The regional potentiometric surface is nearly unaffected by pumping, and the artesian pressure is high enough that wells made in the Mississippi alluvial plain and in the lowlands along streams in western Tennessee and Kentucky will flow.

Results of aquifer tests in Kentucky and Tennessee show coefficients of transmissibility of 32,000 gpd per foot and 25,000 gpd per foot [13]. Based on these results, large wells in the McNairy Sand may be expected to yield as much as 1,500 gpm (with 100 feet of drawdown) at favorable locations in the area.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOHYDROLOGIC MAP OF THE RIPLEY FORMATION, MCNAIRY SAND, AND NACATOCH SAND

FIGURE 60

Water from present areas of use in the McNairy Sand is low in dissolved solids and is generally a calcium bicarbonate type. The dissolved-solids content of the water increases to the west and south, becoming slightly saline southwest of a line extending from Craighead County, Ark., through Memphis, Tenn., to Calhoun County, Miss.

The Nacatoch Sand in southwest Arkansas crops out in Clark, Hempstead, and Nevada Counties and dips to the southeast at a rate of about 30 feet per mile. Although most wells in the formation are for domestic and stock use, some municipal water-supply wells are reported to yield as much as 300 gpm.

The results of one pumping test made in Hempstead County, Ark. [12], show a coefficient of transmissibility of 3,600 gpd per foot. This value is probably representative for the rather limited area in which the aquifer contains fresh water (figure 60).

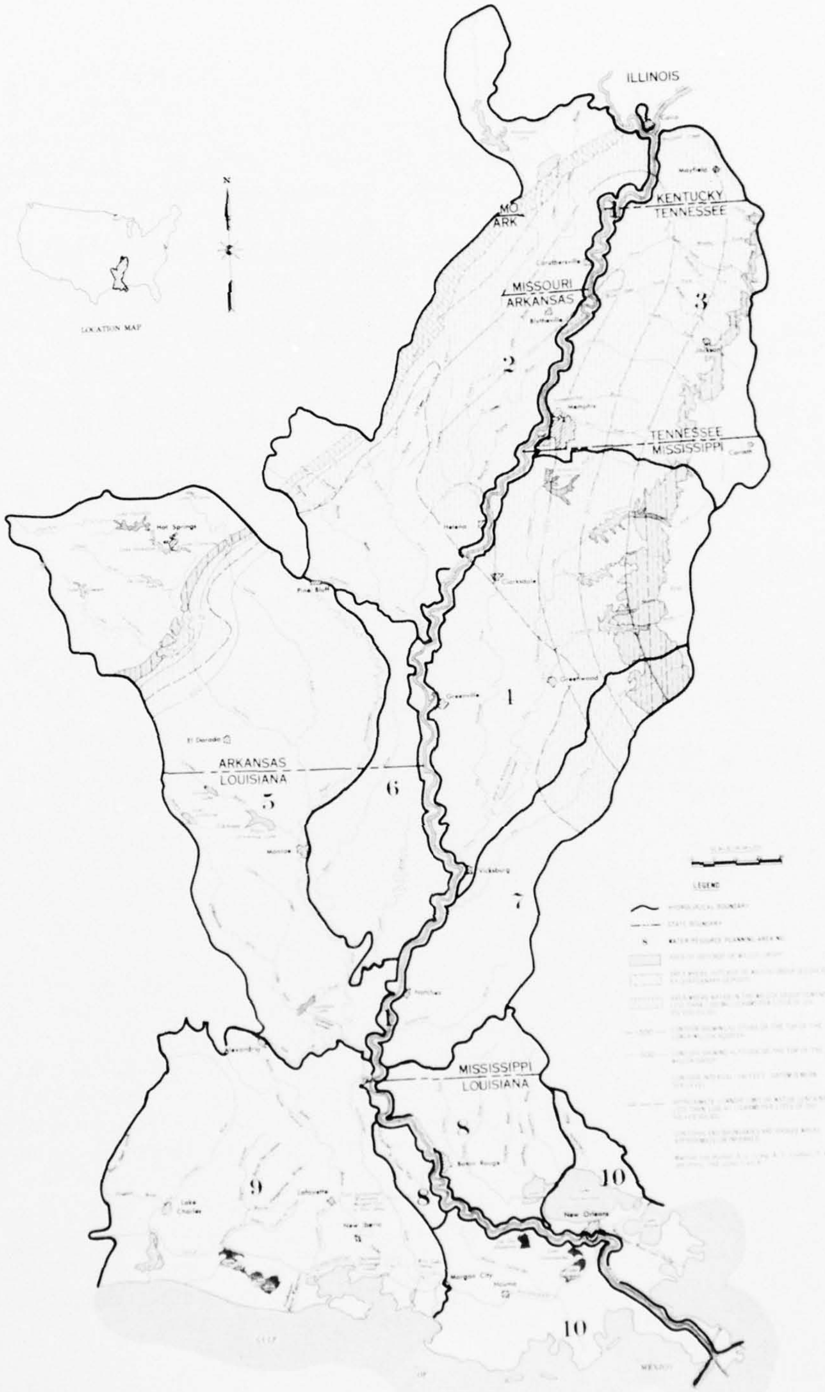
Tertiary Aquifers

The Tertiary System includes several major aquifers in the Eocene, Miocene, and Pliocene Series. These aquifers are separated from the Cretaceous aquifers by several hundred feet of clay in the Midway Group and are themselves separated in most places into two large groups by a thick Late Eocene clay (the Jackson Group).

The oldest Tertiary aquifers are in the Wilcox Group, which crops out in the uplands in WRPA's 3, 4, and 7 and in small areas in the northern part of WRPA 5. The Claiborne Group includes the Meridian-upper Wilcox aquifer, Carrizo Sand, Sparta Sand, Cockfield Formation, and minor aquifers in or equivalent to the Cane River Formation. The Forest Hill Sand and Vicksburg Group, of Oligocene age, are minor aquifers that are limited in areal extent and water-bearing capacity. The Miocene Series includes the Catahoula Sandstone and the Hattiesburg, Pascagoula, and Fleming Formations (for this study, all except the Catahoula Sandstone are classified as undifferentiated Miocene or Upper Miocene deposits). Miocene aquifers crop out in the southern part of WRPA's 4 and 7 and in a small area in WRPA 9. Much of the Miocene outcrop is covered by Quaternary deposits. The Pliocene Series overlies the Miocene in Louisiana and is in turn overlain by Quaternary deposits.

The Wilcox Group includes the lower Wilcox aquifer and minor aquifers in the middle and upper parts (figure 61). The lower Wilcox aquifer contains fresh water in WRPA's 2, 3, 4, and 7. Irregular sand beds in the middle and upper parts of the group contain fresh water in WRPA's 2, 4, 5, and 7.

The lower Wilcox aquifer includes in Tennessee the Fort Pillow Sand [65], which is correlative with the "1,400-foot" sand of the Memphis area and eastern Arkansas. As a result of overlap by the Claiborne Group, the lower Wilcox aquifer is exposed at the surface only in a



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOHYDROLOGIC MAP OF THE WILCOX GROUP

FIGURE 61

narrow belt in Kentucky, northern Mississippi, and Tennessee. The aquifer subcrops in Arkansas and Missouri beneath the Quaternary alluvium.

Recharge to the lower Wilcox aquifer is by precipitation on the outcrop, by infiltration of water from overlying Quaternary terrace and alluvial deposits, and by leakage from the overlapping sands of the Claiborne Group. Ground water movement is toward the axis of the Mississippi embayment.

About 10 percent of the water supply at Memphis is derived from the lower Wilcox. The aquifer is the primary source of ground water at West Memphis, Ark., and Jackson, Tenn., and at several smaller municipalities in northeastern Arkansas and northwestern Mississippi. Presently in northwestern Mississippi there is a trend toward developing the lower Wilcox for public and industrial water supplies because water from shallower sources requires treatment. The aquifer contains fresh water at depths of more than 2,000 feet in parts of WRPA's 2 and 4.

An excellent aquifer, the lower Wilcox in much of the area is capable of yielding 500 gpm or more to large wells. The largest yield reported is 2,000 gpm at West Memphis, Ark., and a well at Memphis yields 1,600 gpm [19]. Although the aquifer thins to the north and south of the Memphis area, it is capable of yielding as much as 600 gpm to wells at many locations in Arkansas, Kentucky, Mississippi, and Missouri. Results of pumping tests indicate coefficients of transmissibility ranging up to about 160,000 gpd per ft. The coefficient of permeability exceeds about 500 gpd per square foot in the Memphis area [19].

Water in the lower Wilcox aquifer is generally soft and is a sodium bicarbonate type. The most troublesome chemical constituent is iron, which occurs in concentrations of more than 0.3 mg/l in some areas. The dissolved-solids content of the water is less than 500 mg/l.

The ground water withdrawals from the lower Wilcox aquifer are estimated to total about 50 mgd. The aquifer is capable of yielding at least 150 mgd without serious consequences.

Irregular sand beds of limited areal extent and thickness occur in the middle and upper parts of the Wilcox Group in WRPA's 2, 4, 5, and 7. In some places, these minor aquifers are capable of yielding several hundred gallons per minute. These aquifers are important because they are good sources of ground water in some localities where the lower Wilcox aquifer is not capable of meeting water requirements. In other localities, the irregular Wilcox sands, though low yielding, contain water of excellent quality. Ground water withdrawals from these sources are estimated to total about 5 mgd in the Lower Mississippi Region.

The Claiborne Group in Arkansas and Louisiana includes, in ascending order, the Carrizo Sand, Cane River Formation, Sparta Sand, Cook

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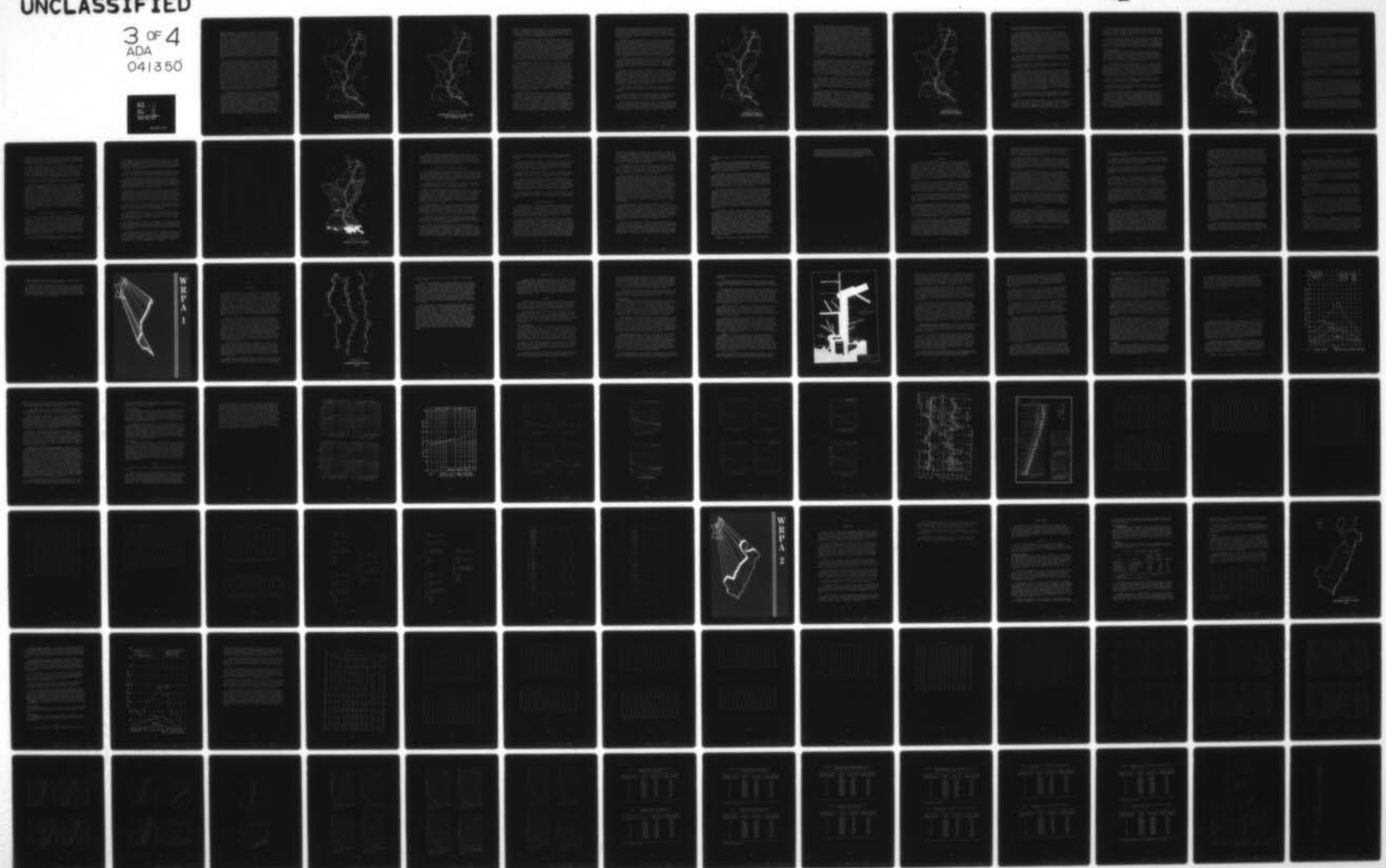
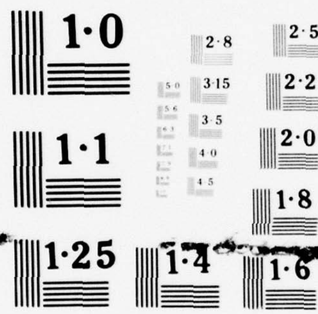


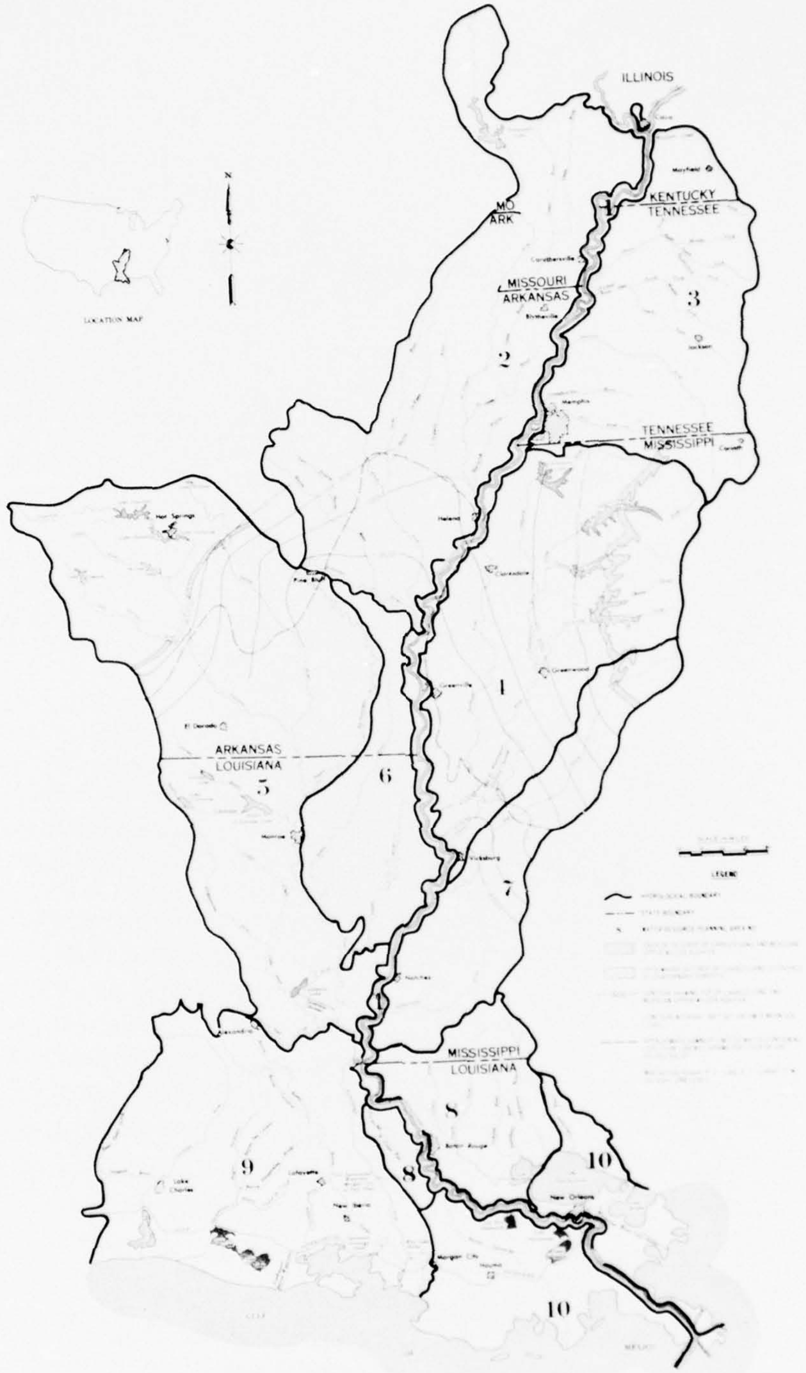


NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Mountain Formation, and Cockfield Formation. The Cane River and Cook Mountain Formations, composed mostly of clay in southern Arkansas and Louisiana, become sandy northward and the Cane River merges into the lower part of the Memphis aquifer. In Mississippi, the Claiborne Group comprises, in ascending order, the Tallahatta Formation (which includes the Meridian Sand Member at the base), Winona Sand, Zilpha Clay, Sparta Sand, Cook Mountain Formation, and Cockfield Formation. The Meridian Sand Member and the uppermost irregular sand beds in the Wilcox Group, hydraulically connected, form the Meridian-upper Wilcox aquifer. The remainder of the Tallahatta Formation and the Winona Sand, equivalent to part of the Cane River Formation, are minor aquifers in most of Mississippi; however, in northern Mississippi the proportion of sand increases and the units merge into the Memphis aquifer (figure 63). The Memphis aquifer (recently renamed Memphis Sand in Tennessee) is equivalent to all strata from the base of the Claiborne Group to the top of the Sparta Sand.

The Carrizo Sand consists of fine to coarse gray micaceous sand. In that part of the Lower Mississippi Region where it contains fresh water (figure 62), the Carrizo ranges from less than 100 to more than 300 feet in thickness and commonly is composed of more than 80 percent sand. The aquifer has not been used extensively in Arkansas, and the few aquifer-test data available do not reflect the hydraulic characteristics that probably characterize the downdip areas. Based on aquifer test results from the Meridian-upper Wilcox aquifer in northwestern Mississippi [71], the Carrizo Sand in eastern Arkansas would have a coefficient of permeability in the magnitude of 200 to 500 gpd per square foot and transmissibilities ranging from 10,000 to over 100,000 gpd per foot. Wells yielding several hundred to several thousand gallons per minute from the Carrizo are feasible. Water from the Carrizo in the Lower Mississippi Region commonly contains more than 500 mg/l of dissolved solids and is a sodium bicarbonate or sodium chloride type. In the Lower Mississippi Region, withdrawals from the Carrizo presently amount to less than 1 mgd. The aquifer is capable of yielding 40 to 50 mgd without an excessive decline in water levels.

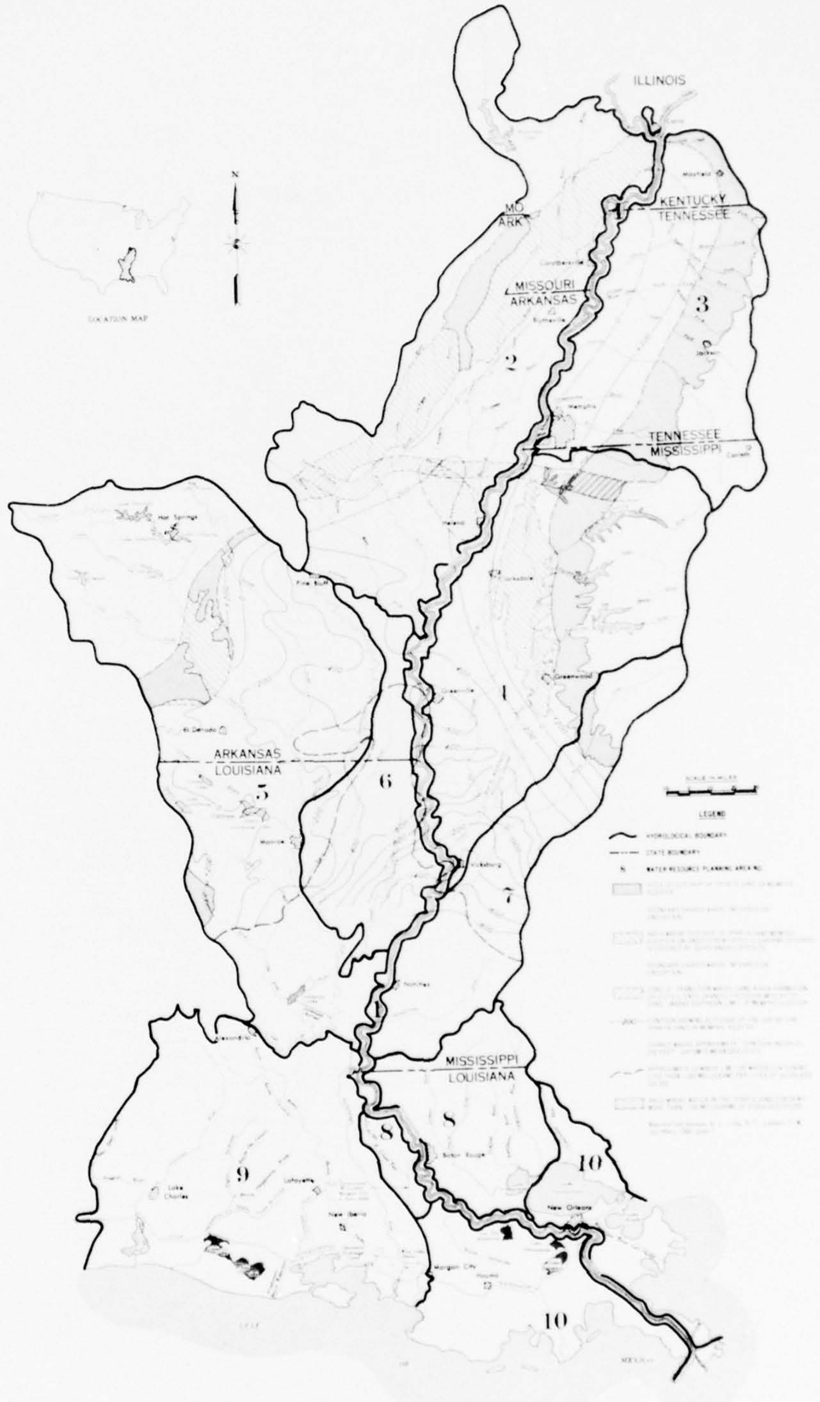
In northwestern Mississippi, the Meridian-upper Wilcox aquifer (figure 62) comprises the Meridian Sand Member of the Tallahatta Formation and hydraulically connected sand in the upper part of the Wilcox Group. The Meridian Sand Member is the stratigraphic equivalent of the Carrizo Sand; the units have hydraulic continuity and both merge into the lower part of the Memphis aquifer. The Meridian-upper Wilcox aquifer is extremely irregular in thickness and lithology, being made up of irregular sand beds representing different geologic units. The irregularity of the aquifer contributes to the wide variation in hydraulic characteristics. Coefficients of transmissibility ranging from less than 10,000 gpd per foot to nearly 90,000 gpd per foot have been determined, and the average permeability is about 400 gpd per square foot. Well yields of more than 2,000 gpm have been reported, but in many places the



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOHYDROLOGIC MAP OF THE CARRIZO SAND AND THE MERIDIAN-UPPER WILCOX AQUIFER

FIGURE 62



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOHYDROLOGIC MAP OF THE SPARTA SAND AND THE MEMPHIS AQUIFER

FIGURE 63

aquifer is capable of only low yields. Water from the Meridian-upper Wilcox is generally of good quality but in some places requires treatment for iron removal or pH adjustment. In the Lower Mississippi Region, withdrawals in 1970 amounted to about 25 mgd, only a small part of a potential yield estimated at nearly 90 mgd.

In the Lower Mississippi Region, the Tallahatta Formation (exclusive of the Meridian Sand Member) is composed of irregular beds of fine to medium sand, clay, and siltstone. The formation is overlain by and hydraulically connected locally to the Winona Sand, a marly, glauconitic sand. Both formations merge northward into the Memphis aquifer. The irregular sand beds in the Tallahatta are sources of water for many low yielding wells; however, in a few localities the formation is capable of yielding several hundred gallons per minute to wells. The Winona Sand is a common source of water for small wells and is capable of only low yields. Both aquifers contain water that is generally suitable for domestic use without treatment; however, the water is generally more highly mineralized than water from either the underlying Meridian-upper Wilcox aquifer or the Sparta Sand, the next overlying aquifer.

Cropping out on the east and west sides of the Mississippi embayment and underlying the entire central part of the Lower Mississippi Region, the Sparta Sand (figure 63) is exceeded in areal extent only by the Mississippi River Valley alluvial aquifer. The Sparta ranges in thickness from a few feet where erosional remnants underlie the Mississippi River alluvium to more than 900 feet in Arkansas and more than 1,000 feet in Louisiana and Mississippi in areas near the downdip limit of fresh water. The Sparta is composed of irregular beds of sand and clay, some of which persist over very large areas. Although the Sparta forms a single regional aquifer system, at some localities the formation may contain three or more separate zones. The transmissibilities determined from pumping tests using wells screened in the Sparta range from less than 20,000 gpd per foot to 140,000 gpd per foot; however, these tests generally are indicative of the characteristics of one zone, and the aggregate transmissibility in many areas could exceed 300,000 gpd per foot. The average permeability of the Sparta is about 500 gpd per square foot [71].

Wells for public and industrial water supplies made in the Sparta Sand commonly yield 1 mgd or more. Yields of over 2,000 gpm have been reported and larger yields are feasible. Water from the Sparta is of good quality, suitable in many areas for general use without treatment. In other localities, treatment for iron removal or pH adjustment is needed and in some areas the water is highly colored by organic material in the aquifer. In a small area in Arkansas and in extreme downdip locations, the Sparta contains saline water. In 1970, the estimated withdrawal of water from the Sparta in the Lower Mississippi Region was about 200 mgd, about half of the estimated potential yield of slightly more than 400 mgd under moderate drawdown conditions. A recent report

on the Sparta Sand [87] indicates that the Sparta, now overdeveloped in some places, has experienced an average water level decline of about 70 feet during a period of 80 years in the Lower Mississippi Region. Because the average pumping rate during the period was much lower than the present 200 mgd, increases in withdrawals from the Sparta should be carefully planned.

The Memphis aquifer (figure 63) is second only to the Mississippi River Valley alluvial aquifer as a potential source of large quantities of ground water in the northern part of the Lower Mississippi Region. Because the aquifer not only underlies the alluvial plain but also underlies much of the coastal plain parts of Kentucky and Tennessee, it is perhaps the most important source of ground water in the northern part of the region. Recharge to the Memphis aquifer is mostly by precipitation on the outcrop in Western Kentucky and Tennessee; however, in the future additional recharge will occur through leakage from shallower sources, particularly the Mississippi River Valley alluvial aquifer.

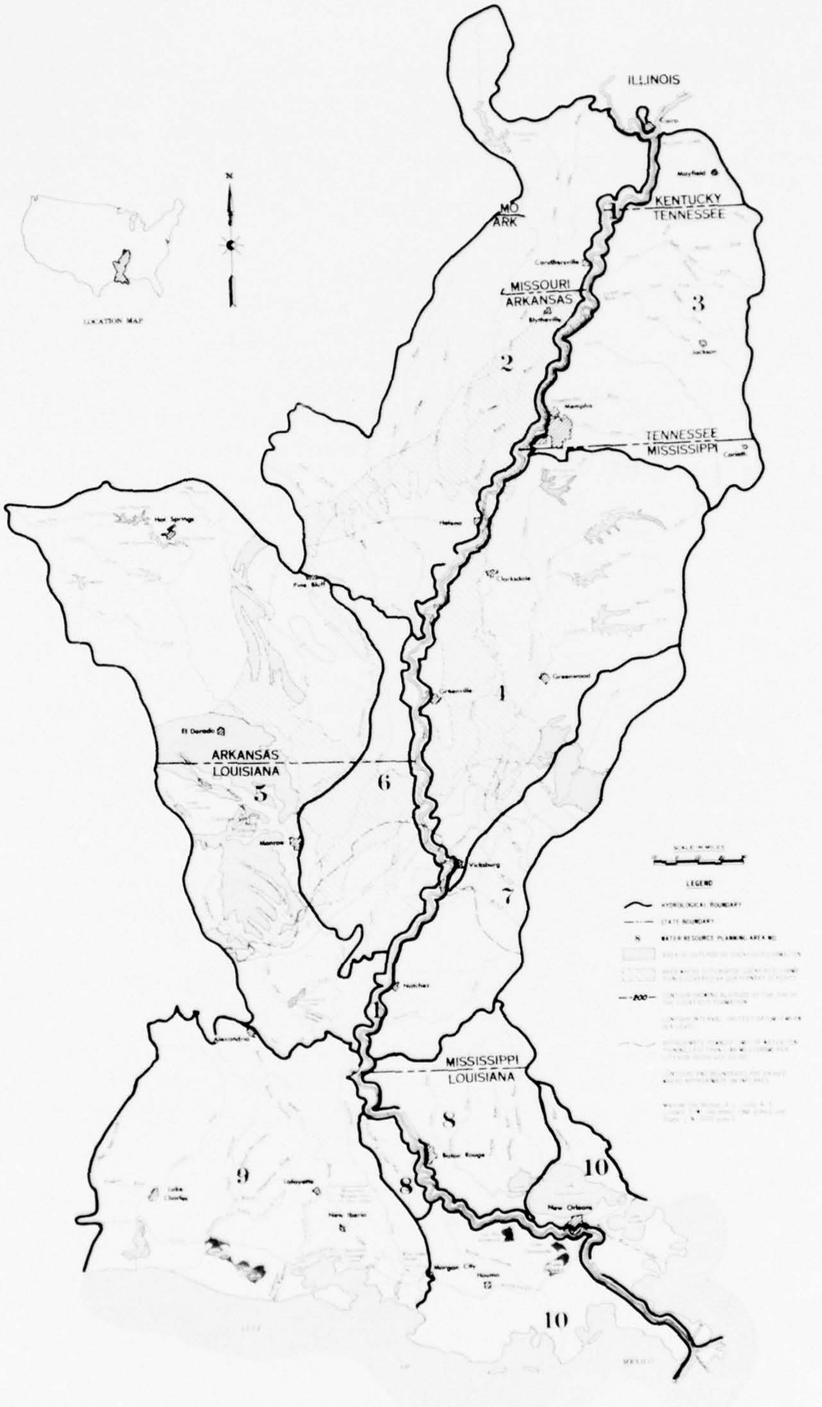
The Memphis aquifer, composed of interbedded sand and clay, ranges from less than 400 feet to more than 800 feet thick. The principal direction of ground water movement is westward from the recharge area in the western part of Kentucky and Tennessee; however, a large cone of depression has developed as a result of withdrawals in the Memphis area [87].

Aquifer test results indicate coefficients of transmissibility ranging from 20,000 gpd per foot to 410,000 gpd per foot. Tests in the Memphis area showed an average transmissibility of 250,000 gpd per foot and the highest value reported, 410,000 gpd per foot, was for a well at Memphis [19]. Assuming average hydraulic conditions, wells yielding more than 1,500 gpm might be constructed at many localities underlain by the Memphis aquifer. In Kentucky, the Tallahatta Formation and Sparta Sand, partial equivalents of the Memphis aquifer, yield as much as several hundred gallons per minute to wells [27].

Water from the Memphis aquifer is generally of good quality. In some areas, treatment is required for iron removal, pH adjustment, or hardness.

The present pumpage from the Memphis aquifer is estimated to be about 200 mgd, of which about 180 mgd is withdrawn in the Memphis area. The aquifer has the capability of transmitting large quantities of water, and the estimated potential yield is about 1,050 mgd.

The Cockfield Formation crops out on both the east and west sides of the Mississippi embayment and underlies much of the Mississippi River alluvium in the central part of the Lower Mississippi Region (figure 64). In the area where it contains fresh water, the Cockfield is composed of fine to medium quartz sand, silt, and clay ranging in thickness from



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOHYDROLOGIC MAP OF THE COCKFIELD FORMATION

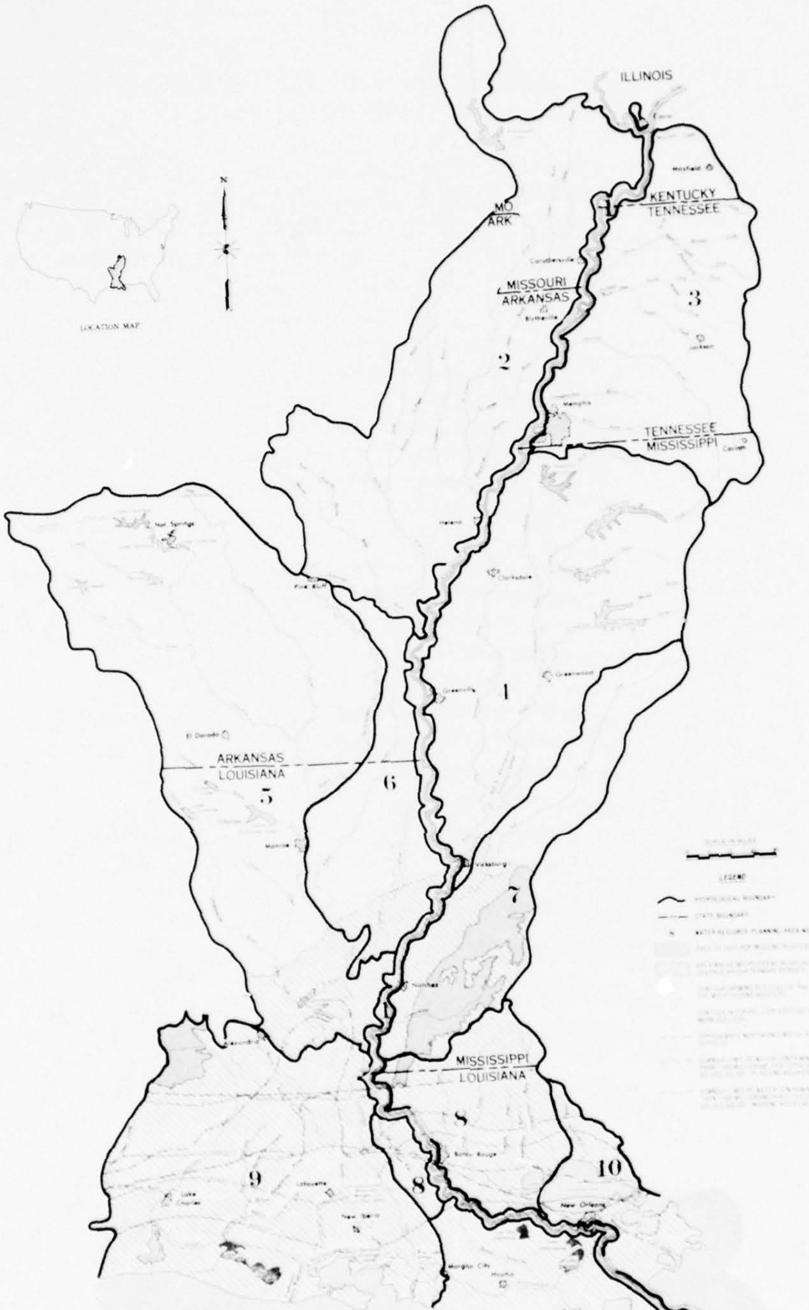
FIGURE 64

less than 100 feet in the north to about 600 feet in the Vicksburg, Miss., area. Sand beds are discontinuous throughout and commonly contain carbonaceous material. The Cockfield is similar in hydraulic characteristics to the Sparta Sand, having an average permeability in Mississippi of about 500 gpd per square foot [71], and transmissibilities as high as 160,000 gpd per foot have been reported [111]. However, the hydraulic characteristics vary and values of less than 10,000 gpd per foot would not be unusual. The largest yields reported for wells tapping the Cockfield are at Greenville, Miss., where wells commonly yield more than 1,000 gpm and the largest reported yield is 2,100 gpm. In most of the region, however, much lower yields are usual. Water in the Cockfield is generally of good chemical quality; however, in much of the region the water is colored by organic material in the aquifer. In some places, treatment for iron removal or softening is required. The estimated withdrawal of water from the Cockfield for public and industrial use in 1970 was estimated to be about 35 mgd. The largest withdrawals, about 14 mgd, were made in the Greenville-Leland, Miss., area. The estimated potential yield of the aquifer is about 75 mgd.

Aquifers of Oligocene age in the Forest Hill Sand and the Vicksburg Group are very limited in yield and in areal extent. These aquifers are significant primarily because they are the only sources of fresh ground water between the top of the Claiborne Group (generally more than 500 feet deeper) and the base of aquifers in the Miocene Series. Both units include sand beds capable of yielding good quality water in quantities sufficient for domestic and stock wells. In a few places, the aquifers are capable of furnishing small community or industrial supplies. In the Lower Mississippi Region, utilization of these aquifers is limited to parts of Claiborne, Warren, and Yazoo Counties, Miss.

Miocene deposits underlie about the southern one-third of the Lower Mississippi Region, roughly southward from the latitude of Vicksburg, Miss. (figure 65). The beds dip southward and are overlain by Pliocene deposits south of the 31st parallel. Both sequences are overlapped by Quaternary deposits and, except for small Miocene outcrops in west-central Louisiana and southwestern Mississippi, are not exposed at the surface.

Lithologically, the Miocene and Pliocene deposits are virtually identical; the boundary between the two is established on the basis of paleontologic evidence. Together, they form a gulfward-thickening wedge of interfingering sand, silt, and clay beds many thousands of feet thick at the southern limit of the area. The sands are fine to medium grained, discontinuous, and interconnected to varying degrees. Collectively, they are considered a hydrologic unit in Louisiana in this report and are referred to as the Mio-Pliocene aquifer. In Mississippi, the Miocene is divided into the Catahoula Sandstone and the Hattiesburg and Pascagoula Formations. The Hattiesburg and Pascagoula Formations have



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOHYDROLOGIC MAP OF THE MIO-PLIOCENE AQUIFERS

FIGURE 65

not been satisfactorily differentiated in the subsurface and are here considered undifferentiated upper Miocene aquifers.

The Catahoula Sandstone is the only artesian aquifer capable of yielding large quantities of ground water in the northern one-half of the southern part of WRPA 7. In the remainder of the southern part of the area, the Catahoula is overlain by undifferentiated upper Miocene strata of similar lithologic and hydrologic characteristics. The units comprise a thick section of irregular sand and clay beds that are hydraulically connected in varying degrees. The water-bearing capacity of the aquifers increases southward due to the thickening of the units and the increase in the number of aquifers. Aquifer tests indicate transmissibilities for individual sand beds ranging up to about 100,000 gpd per foot. Although the highest yield reported for a well in the southern part of WRPA 7 is about 800 gpm, much higher yields can be obtained, especially in areas underlain by two or more sand beds.

Water from the Catahoula Sandstone and the undifferentiated upper Miocene aquifers is generally a sodium bicarbonate type. In present areas of use, the water is low in dissolved solids but commonly requires treatment for iron removal or acidity.

In 1970, about 17 mgd of ground water was withdrawn from the Miocene aquifers in WRPA 7. Yield of the Miocene aquifers is conservatively estimated to be at least 70 mgd.

Individual sand beds in the Mio-Pliocene dip and thicken somewhat to the south. Thickness varies, as sands pinch out as well as coalesce with other sands; but most of the thicker and more extensive sand beds are in the 50- to 200-foot thickness range. Coalescence of sand beds results in locally massive sand beds several hundred feet thick. The sands are uniformly graded, and coefficients of permeability are generally in the 250- to 1,000-gpm-per-square-foot range. Because of the variation in sand thickness, coefficients of transmissibility vary over a wide range; however, most are on the order of 100,000 to 300,000 gpd per foot. Well yields are high, and yields of 1,000 to 3,000 gpm are obtainable in most of the area; even higher yields have been obtained by screening all or nearly all available sands.

Except for declines caused by concentrated pumpage in the Baton Rouge area, water levels are still high. Flowing wells may be obtained in WRPA's 8 and 10, and large yields are common, the largest being 3,200 gpm.

Water in the Mio-Pliocene aquifer is a soft sodium bicarbonate type where it is fresh, but the quality may be affected locally by water movement from overlying deposits. It is generally low in iron content and may be corrosive. Downdip, the water becomes salty. A so-called "ridge" of salty water occurs in south-central Louisiana where sands

beneath the Quaternary deposits do not contain fresh water. East and west of this "ridge," the Miocene and Pliocene sands contain fresh water to rapidly increasing depths. The maximum depth of fresh water is about -3,000 feet msl west of the "ridge" in WRPA 9 and about -3,500 feet msl east on the "ridge" in WRPA's 8 and 10.

Nearly 200 mgd is withdrawn from the Mio-Pliocene aquifer, and more than half of this amount is pumped in the Baton Rouge area. Almost all the water is used for municipal and industrial purposes. An additional 15 to 20 mgd flows to waste from uncapped flowing wells in southeastern Louisiana. On a regional basis, the aquifer is relatively undeveloped. Properly planned development can produce many times the present pumpage.

Quaternary Aquifers

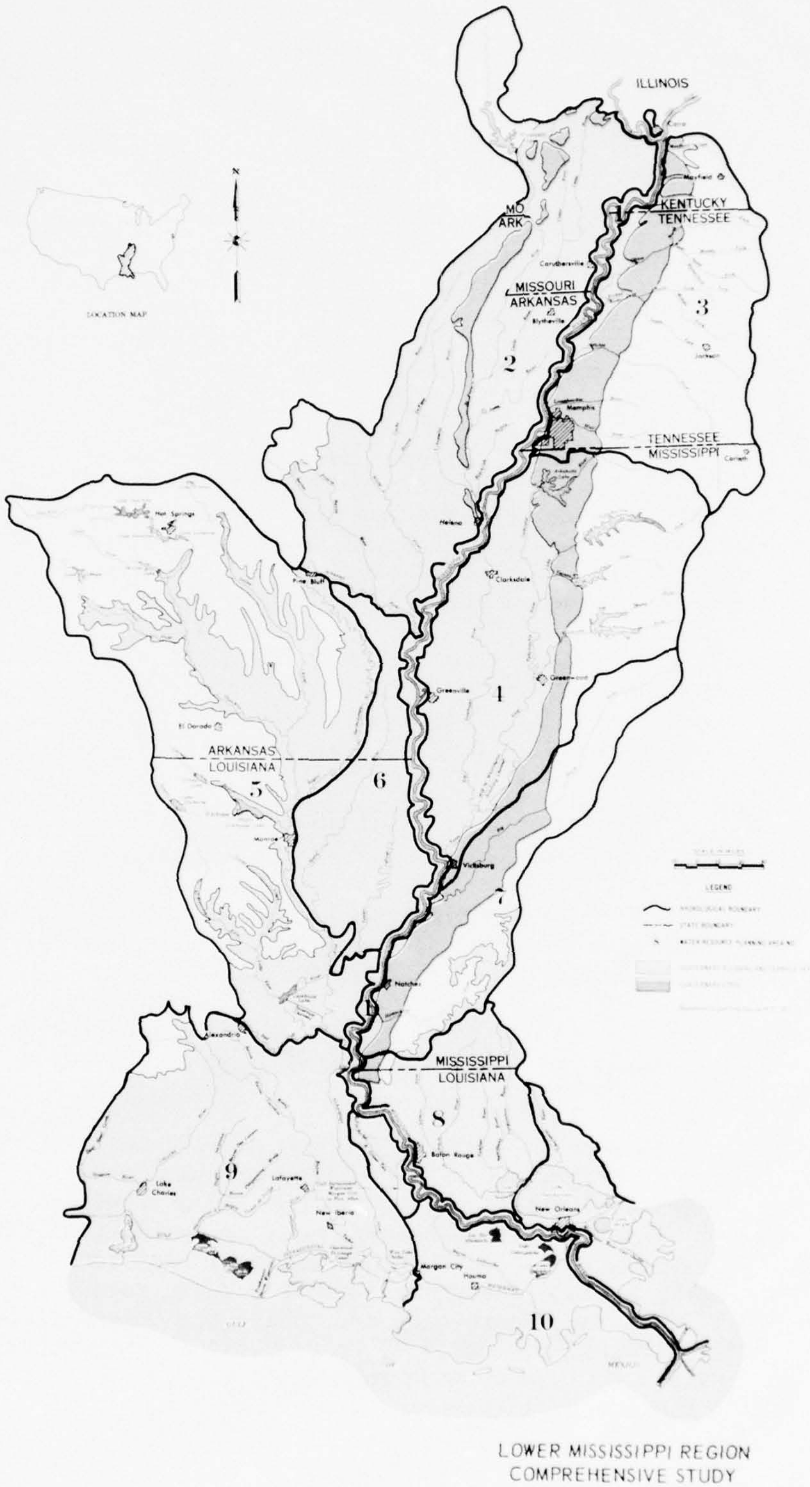
South of a line projected through the east-west boundary between Louisiana and Mississippi, the Quaternary deposits form a gulfward-thickening wedge of alternating sand and clay beds. Quaternary deposits also occur as stream terrace and alluvial valley fill in most of the Lower Mississippi Region. Both the deltaic wedge and the thinner alluvium contain fresh water-bearing aquifers (figure 66).

The Citronelle Formation (considered by the U. S. Geological Survey to be of Pliocene age in Mississippi) includes beds of sand and gravel that are here considered part of the Quaternary aquifers in the Lower Mississippi Region. The Citronelle in Mississippi caps hills and ridges and thickens southward. In Louisiana, equivalent strata are included with Pleistocene deposits. The Citronelle in Mississippi, dissected and drained by streams, is generally a water table aquifer. In Louisiana, the aquifer dips beneath younger strata and becomes artesian.

Water from the Citronelle Formation is soft and low in dissolved solids. It is generally not satisfactory without treatment for most uses due to the low pH and high iron content.

In many areas, the saturated thickness of the Citronelle is 50 to 100 feet and the aquifer is capable of yielding several hundred gallons per minute to large-diameter wells.

The Pleistocene terrace deposits thicken rapidly south of the 31st parallel and form a thick wedge of interfingering sand and clay beds. The sands are characteristically discontinuous and are interconnected to varying degrees. They constitute a large aquifer system that extends throughout approximately the southern one-third of Louisiana. The sands are fine- to coarse-grained and graveliferous and are somewhat coarser in southwestern Louisiana, where they are called the Chicot-Atchafalaya aquifer. The Pleistocene aquifer is better developed in southwestern than in southeastern Louisiana, and fresh water occurs deeper and farther downdip to the south.



LOWER MISSISSIPPI REGION
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QUATERNARY DEPOSITS

FIGURE 66

Transmissibilities of the aquifer east of the Mississippi River are generally less than 200,000 gpd per foot; however, larger wells produce as much as 1,500 gpm. West of the river transmissibilities are much higher, as much as 1,000,000 gpd per foot for individual sand beds, and larger wells yield 1,000 to 4,000 gpm.

The quality of water in the Pleistocene aquifer is also different in southeastern and southwestern Louisiana. In southeastern Louisiana the water is generally soft, low in dissolved-solids content, and corrosive, except where affected by movement of hard water from the alluvial aquifer. In southwestern Louisiana, however, the water is generally a hard, calcium magnesium bicarbonate type, and high in iron content. In both areas, the water becomes salty downdip and with depth.

Sediments of Pleistocene and Holocene age comprise the Mississippi River Valley alluvial aquifer, which is a depositional feature of the Mississippi River system. The older Pleistocene alluvium is terraced, forming dissected surfaces higher than the present floodplains of major streams. The Pleistocene alluvium generally contains coarse sand or graveliferous sand at its base and grades finer upward; Holocene alluvium is composed of very fine-grained sand, silt, and clay. The Holocene sands are water bearing and are part of the Mississippi River Valley alluvial aquifer, but the Pleistocene alluvium is the major and most productive part of the aquifer.

The terrace deposits are dissected, and many segments are isolated and act as individual aquifers. The alluvial aquifer is also divided on a regional scale. Crowleys Ridge and the Mississippi River are boundaries that separate the aquifer into three major hydraulically independent units.

Ground water in the alluvium contributes to the base flow of streams it underlies. The natural direction of movement of water toward the streams is temporarily reversed during periods of high river stage. Seasonal reversals generally do not represent significant recharge to the aquifer, as most of the stored water is discharged to the stream as the stage lowers. Recharge from streams has been induced locally, such as along the White River in Arkansas, where heavy withdrawals have sufficiently lowered water levels adjacent to major streams. Most of the recharge to the aquifer is from precipitation. However, many portions of the aquifer are recharged by underflow where fine-grained surficial deposits inhibit direct recharge.

Thickness of the aquifer is highly variable, partly because the Quaternary sediments were deposited on an eroded, irregular Tertiary surface; thickness ranges from less than 50 feet to more than 250 feet. In addition, texture of the aquifer material ranges from very fine sand to gravel. Because of these large differences in thickness and texture, aquifer characteristics also vary over a wide range. Coefficients of

permeability range from less than 500 to more than 3,000 gpd per square foot, and coefficients of transmissibility range from less than 40,000 to about 600,000 gpd per foot. Well yields as high as 5,000 gpm are obtainable, and yields of 2,000 gpm are common.

Water from the Mississippi River Valley alluvial aquifer is generally hard, a calcium bicarbonate type, and high in iron content. Where the older alluvial or terrace deposits are exposed, the water may be soft, low in dissolved-solids content, and corrosive. Temperature ranges from about 59° F in the northern part of the region to about 70° F in the southern part; seasonal variations occur in the vicinity of major streams where they are hydraulically connected to the aquifer.

The alluvial aquifer of the Red River Valley merges with and is very similar to the Mississippi River Valley alluvial aquifer.

Most of the ground water withdrawn in the Lower Mississippi Region is pumped from Quaternary aquifers. The chief uses are agricultural and industrial. The most widespread water level declines brought about by pumping have occurred in eastern Arkansas and southwestern Louisiana. Surficial clays in eastern Arkansas prevent direct recharge in a large area where rice irrigation makes large seasonal demands on the ground water supply. Heavy pumping by industry as well as agriculture has produced a large cone of depression in southwestern Louisiana where nearly 1,000 mgd is withdrawn. In spite of large present withdrawals, Quaternary aquifers have good regional potential for further development. Some areas along major streams are especially favorable where the stream is in direct hydraulic connection with the alluvial aquifer; in such areas, large supplies can derive most of their pumpage from direct stream recharge without producing far-reaching effects on the remainder of the aquifer.

Estimated Yield Under Specified Conditions

The estimated yield of an aquifer may be based on the ability of an aquifer to yield water under stated conditions and with acceptable consequences. Estimates of the yields of aquifers in the Lower Mississippi Region are based on methods used by Boswell in a study of ground water availability in the same area [11]. Basically, these methods describe yields that might result while lowering water levels in artesian aquifers an average of 100 feet in 50 years and lowering water levels in Quaternary alluvial aquifers 40 feet during the same period. For this study, the yield resulting from an average lowering of 200 feet in each artesian aquifer is added, and the more pronounced consequences of the additional lowering are considered.

One of the economic consequences of declining water levels is the increase in the cost of power for pumping water. One of the reasons

for limiting the average lowering of water levels to 200 feet is that average pumping lifts would be nearly 500 feet (assumptions: original level, 100 feet underground; 60-psi head at land surface; 35 feet of drawdown in pumping well). The cost of electric power to pump one million gallons of water is approximately five dollars for each 100 feet of lift (at 1 cent per kwh).

Other considerations involved in determining acceptable water level declines include land subsidence, updip movement of saline water, and the effects of lowered water levels in the recharge (outcrop) area.

Water level declines in response to increasing withdrawals are accompanied by steeper hydraulic gradients, which result in an increase in the quantity of water moving through the aquifers. The increase in quantity will continue until either the maximum possible gradient is obtained without decreasing the saturated thickness or until discharge equals potential recharge plus change in storage.

The yield of water table aquifers is directly related to recharge. The Quaternary alluvial aquifers in the Lower Mississippi Region are recharged mostly by precipitation on the surface. Rates of recharge for areas in the region where surficial materials are sufficiently permeable to permit direct recharge are estimated to range from 2 to 5 inches annually; however, surficial deposits in some very large areas (the Grand Prairie Region, for example) apparently are relatively impermeable.

The estimates for yields of aquifers in the Lower Mississippi are given in table 23. It is acknowledged that some areas now yield more ground water than the quantities shown; however, these areas already are experiencing the problems of local overdevelopment.

The ground water yield at any site is the total combined yield of all aquifers underlying the site. The yield at any site in the Lower Mississippi Region can be estimated by referring to figure 67. Other maps showing areas where each individual aquifer can be utilized are included for each WRPA.

The highest yielding aquifer in the region is the Mississippi River Valley alluvial aquifer. In much of the alluvial valley, older artesian aquifers underlie the alluvial aquifer, adding to the potential yield and allowing a choice of sources on the basis of water quality or other considerations.

Estimated yield in this study is based on a uniform distribution of ground water withdrawal over the entire area. In practice, most water will be withdrawn in concentrated areas and ground water will move toward the area of withdrawal. As a result, water produced at some places may be partly derived from other WRPA's; for example, water pumped in the Memphis area is derived from WRPA's 2, 3, and 4.

Table 23 - Availability of Fresh Ground Water in the Lower Mississippi Region

Aquifer	Water Resources Planning Areas (Total yield, in mgd)																			
	2		3		4		5		6		7		8		9		10		Total	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Water-[illegible] aquifers[a] (Includes Mississippi River valley alluvial aquifer, other alluvial aquifers, and aquifers in terrace deposits)	3,155	3,155	370	370	1,720	1,720	2,495	2,495	1,932	1,932	116	116	414	414	595	595	46	46	10,843	10,843
Artesian aquifers[b]																				
Pleistocene	--	--	--	--	--	--	--	--	--	--	--	--	120	180	--	--	80	120	200	300
Mio-Pliocene	--	--	--	--	--	--	--	--	--	--	--	--	228	360	355	404	100	190	683	954
Chicot	--	--	--	--	--	--	--	--	--	--	--	--	--	--	210	320	--	--	210	320
Chicot-Atchafalaya	--	--	--	--	--	--	--	--	--	--	--	--	--	--	830	1,200	--	--	830	1,200
Miocene, undifferentiated	--	--	--	--	--	--	[c]12	[c]12	[c]24	[c]24	30	[d]35	--	--	--	--	--	--	66	71
Catahoula Sandstone	--	--	--	--	--	--	--	--	--	--	30	[d]35	--	--	--	--	--	--	30	35
Cockfield Formation	15	[d]19	--	--	18	25	19	28	12	17	9	11	--	--	--	--	--	--	73	100
Sparta Sand	61	96	--	--	100	142	81	128	9	14	27	38	--	--	--	--	--	--	278	416
Cane River Formation and equivalents	--	--	--	--	[d]10	[d]15	--	--	--	--	--	--	--	--	--	--	--	--	10	15
Memphis aquifer	208	400	260	[e]654	--	--	--	--	--	--	--	--	--	--	--	--	--	--	468	1,054
Carrizo Sand	20	[d]34	--	--	--	--	27	54	--	--	--	--	--	--	--	--	--	--	47	88
Meridian-upper Wilcox aquifer	--	--	--	--	54	73	--	--	--	--	11	15	--	--	--	--	--	--	65	88
Wilcox Group, undifferentiated	23	[d]34	--	--	[d]5	[d]8	[c]19	[c]19	--	--	--	--	--	--	--	--	--	--	47	61
Lower Wilcox aquifer	30	39	34	39	45	60	--	--	--	--	15	19	--	--	--	--	--	--	124	157
Ripley Formation or Eastover Sand	16	40	34	58	5	8	[d]3	[d]6	--	--	--	--	--	--	--	--	--	--	58	112
Coffee Sand	--	--	6	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6	10
Gordo Formation and Tokio Formation	--	--	--	--	[d]8	[d]12	[d]2	[d]4	--	--	[d]1	[d]2	--	--	--	--	--	--	11	18
Paleozoic rocks	[d]3	[d]3	[d]6	[d]8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9	11
Total potential yield	3,531	3,816	710	1,139	1,965	2,063	2,658	2,744	1,977	1,987	239	271	762	954	1,990	2,519	226	356	14,058	15,939

Note:

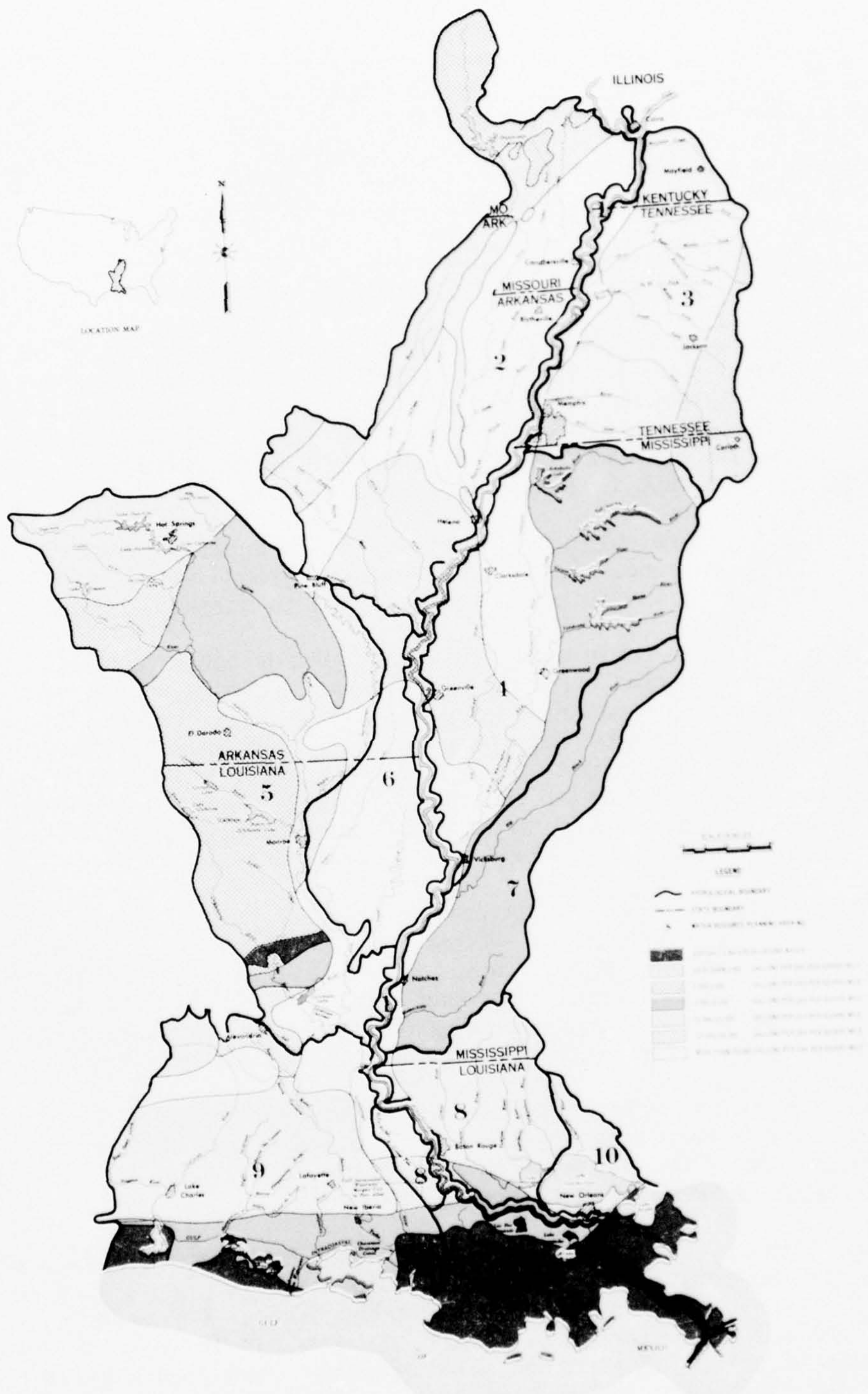
[a]Yields from alluvial aquifers include water removed from storage during 50-year period. At the end of 50 years, withdrawals must be reduced about 10 percent to withdraw only the average annual recharge. Yields from terrace deposits, more permeable than alluvial deposits, are based on an average annual recharge of 6 inches.

[b]Yields from artesian aquifers in column A are based on flowthrough produced by hydraulic gradients resulting from an average drawdown of 100 feet during a 50-year period in each aquifer. Yields in column B are based on an average drawdown of 200 feet or to the top of the aquifer. Modifications of the basic method were used where necessary.

[c]Yield based on maximum hydraulic gradient.

[d]Estimated where basic data are not available.

[e]Yield determined in separate study.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

POTENTIAL YIELD OF AQUIFERS

FIGURE 67

The estimated yield of ground water from the Mississippi River Valley alluvial aquifer and other Quaternary aquifers is based on well fields located away from streams. The yield of the aquifer can be increased by installing lines of wells parallel to and in the vicinity of streams where recharge can be induced; however, this additional water will be subtracted from the surface water resource.

Interrelation of Ground and Surface Water

The hydrologic system in the Lower Mississippi Region is typical of that in a humid region. Precipitation is reasonably distributed through the year, and an abundance of water is available to sustain surface runoff and to replenish aquifers. Much of the region is underlain by permeable terrain where aquifers crop out and are replenished. Regionally, the aquifers are kept full by precipitation.

Generally, more water may be available to aquifers than can move into the artesian zone. Part of the surplus ground water is dissipated by evapotranspiration and part is discharged to streams.

Water in water table aquifers (or the water table part of artesian aquifers) in the region commonly moves toward streams and is discharged. During dry periods, streamflow is derived from this source. Streams originating in areas underlain by permeable water-bearing material may be perennial and the volume of low flow is dependent in part on the hydraulic characteristics of the aquifer material. The water table aquifer acts as a reservoir, temporarily storing precipitation and releasing it gradually to streams.

Streams flood during storm periods and the potentiometric surface in water table aquifers rises. Commonly, there is little movement of water from the stream into the aquifer; rather, the stream has a blocking effect on the discharge of ground water. When flooding subsides, water held in "bank storage" is soon released and the water table aquifer gradually releases the temporarily stored water to the stream.

The volume of water stored in the water table aquifer decreases as a result of (1) evapotranspiration, (2) movement into deeper aquifers, and (3) discharge to streams. As the volume diminishes, the discharge decreases and a recession of streamflow occurs.

One natural factor influencing the low flow characteristics of streams is the relation of the water table to the water surface in the stream; either may adjust to changes in the other. For example, a lowering of the stream surface will result in temporary increase in ground water discharge during a period while the water table adjusts to a lower level; conversely, if the stream level is raised, as by a dam, the water table will rise to accommodate the new condition. The depth to which a

channel is incised into the saturated part of a water-bearing geologic unit determines the quantity of water that can be intercepted by a stream.

Streams lying entirely within the alluvial plain are, under natural conditions, perennial if the channel is incised below the dry season water table; otherwise, the streams are intermittent. The Sunflower River in the Yazoo Basin is an example of a perennial stream whose low flow is sustained by ground water discharge.

Upland streams generally are gaining streams in areas underlain by predominately sandy deposits and are losing streams (to evapotranspiration) where reaches cross relatively impermeable deposits of clay.

Changes in the regimen result in changes in the ground water-surface water relation. Large withdrawals of ground water may lower the water table below the water surface in the streams, thereby reversing the direction of movement on a local or regional basis. Impoundments, by reversing the direction of movement, may have the same effect. Deepening stream channels will temporarily increase ground water discharge to streams, provided the water surface in the streams is lowered.

In summary, water movement in the Lower Mississippi Region is normally from aquifers into streams. During floods, the direction of movement is reversed, but the effect on water table aquifers is temporary and local.

Management Considerations

The primary source of ground water in the Lower Mississippi Region is the Mississippi River Valley alluvial aquifer because (1) it underlies about one-third of the region, and (2) it is the source of more than two-thirds of the potential ground water supply. The estimated yield of the aquifer, about 10,000 mgd, is conservative and does not take into account the large ground water withdrawals that may be made where well fields are proximate to streams.

The Mississippi River Valley alluvial aquifer, like all aquifers, can be overdeveloped and is now overdeveloped in some areas (the Grand Prairie Region in Arkansas, for example). The large potential yield of the aquifer can be attained only by distribution of withdrawals with attention given to variations in hydraulic characteristics. The optimum yield of the aquifer, except in localities where recharge may be induced from surface sources, is directly related to the recharge by precipitation on the surface. Lowering the water table by pumping will increase the storage space in the aquifer. The aquifer will be replenished during the wet season up to the limit of the unsaturated zone to transmit recharge. Hence, the ground water supply in a unit area is limited to

the recharge that might occur in the area if the aquifer is partly dewatered. The maximum recharge rate in the alluvial plain is unknown but is probably in the range of 2 to 6 inches; hence, the ground water yield of the aquifer is approximately 100,000 to nearly 300,000 gpd per square mile. Withdrawals exceeding the recharge rate will reduce the thickness of the saturated zone. The zone of saturation must be kept thick enough to allow for well construction and operation.

Although the Mississippi River alluvial aquifer under natural conditions is generally artesian, water table conditions prevail in some areas. In other areas, water table conditions occur seasonally as a result of pumping for irrigation and, in some areas, water table conditions are permanent as a result of continuous pumping.

Artesian aquifers underlie most of the region and are capable of supplying about one-third of the total ground water resource in the region. Unlike the Mississippi River Valley alluvial aquifer, the artesian aquifers cannot be managed in a manner similar to that used to manage a surface reservoir. The artesian aquifers act as conduits, transmitting water from the outcrop (recharge) area into the subsurface. The quantity of water available from an artesian aquifer is related primarily to the ability of the aquifer to transmit water (a function of physical properties of the aquifer and the hydraulic gradient) and the availability of recharge to meet requirements that may result from increased withdrawals. Some additional water is made available from storage as a result of decreasing pressure. Larger quantities may result from capture of water lost to evapotranspiration, leakage from other aquifers, or water released from pore spaces of fine-grained material during compaction; however, except for leakage these sources of water are temporary.

In this report, the yield of artesian aquifers is estimated for pumping rates that might result from an average drawdown of 100 feet and 200 feet during a 50-year period (table 23). It is felt that an average drawdown of 100 feet throughout most artesian aquifers will not result in serious consequences (dewatering, subsidence, increased pumping lift, and reduction in streamflow) in the Lower Mississippi Region and that the consequences of a 200-foot decline might be acceptable. Larger drawdowns in artesian aquifers would not significantly increase the total yield of the region and the consequences probably would not be acceptable.

The effect of withdrawals on artesian aquifers was demonstrated in a study of the Sparta Sand [87]. During a period of about 80 years, the water level decline in the Sparta averaged about 70 feet throughout the region for an average withdrawal rate of much less than 200 mgd. In several places (Pine Bluff, El Dorado, and Magnolia, Ark., for example), the aquifer is near the point of overdevelopment and alternate sources of water must be found to meet future needs. Similar conditions in the

same or other aquifers at other places may be avoided or minimized by planning.

Water quality is a critical consideration in the utilization of ground water. Ground water suitable for public or special uses without treatment needs to be reserved for these uses. Generally, water of poor quality is available for use where quality is not a consideration. Ground water may be conserved by utilizing water of the poorest quality that may be compatible with any use.

Ground water in the Lower Mississippi Region generally is of good quality, needing treatment only for softening, iron removal, or pH adjustment to meet standards for most uses. Most of the aquifers gradually become saline with increasing depth. The degree of salinity at any location can be estimated, and withdrawals can be made accordingly. One consideration will be in locating withdrawals so as to minimize the updip movement of saline water. Salt-water intrusion in coastal areas is another threat that can be avoided or minimized.

Most of the present overdevelopment of ground water can be alleviated by developing alternate sources of water and reducing ground water withdrawals. Areas where large ground water withdrawals have not yet resulted in overdevelopment should be given careful study to determine optimum development. In the future, large ground water developments might be located in the most favorable parts of the region. These areas include: (1) The Mississippi alluvial plain (except in the area in WRPA 2 south and west of Crowleys Ridge); (2) western Kentucky, northwestern Mississippi, and western Tennessee, specifically, the area underlain by the Memphis aquifer and its equivalents; (3) WRPA 8 except the Baton Rouge area; and (4) WRPA 9 except the coastal area and the Lake Charles area.

Considering the projected needs for ground water in the region, it is essential that all potable water be protected from pollution. The principal source of pollution in the southern part of the region is oilfield wastes. These wastes are commonly discharged into surface pits and allowed to infiltrate into water table aquifers. Brine is commonly injected into subsurface saline zones by injection wells. There should be assurance that injection wells are properly constructed and that the receiving stratum is a saline zone. The practice of injecting through open bore holes below shallow or surface casing does not guarantee against pollution of the fresh water zone. Abandoned wells need to be completely plugged to preclude the movement of water between zones or aquifers, a condition that will be intensified as water levels in fresh water zones decline and hydrostatic head differences become larger. Other sources of pollution are industrial waste, agricultural chemicals, and sanitary land fills.

Management considerations include planned areal distribution of

ground water withdrawals to achieve optimum yield; continued studies of the potential for artificial recharge; reservation of good quality ground water for highest priority uses; better delineation of shallow and intermediate saline water bodies; better delineation of the downdip extent of fresh water; and the utilization of saline water.

NEEDS FOR ADDITIONAL DATA

Climatology

A need exists in climatology of the Lower Mississippi Basin for a better definition of small scale or microscale variations of the many parameters that collectively determine the climate. The required instrumentation and data acquisition efforts should be responsive to indicated or potential needs of specific areas as it would not be economically feasible nor essential that the entire Lower Mississippi Study Region receive this attention to detail. Our very large urban areas, in particular, present gradual climatic changes in temperature and rainfall and other indices such as solar insolation, radiation, air pollution, etc., that are not well enough documented presently to permit reasonable projections.

It should also be recognized that the Arkansas-Mississippi delta area and to a lesser degree the deltas of North Louisiana and the Missouri bootheel section comprise a very important land area that is manipulated by man through extensive crop management procedures and irrigation practices, and this is being done with a very minimum of instrumental monitoring, which is a prerequisite to meaningful research.

For river and flood forecasting, more data and research are required relative to evapotranspiration and soil moisture, and additional solar radiation measurements are desirable to increase the output accuracy of the Hydrologic Conceptual Model being adopted by the National Weather Service.

The developing awareness of our ecology and the ramifications of environmental conservation programs dictate added study and research. Maximum land and water resource utilization becomes increasingly important and attention needs to be devoted to a higher degree of resolution of diurnal changes and to statistical analysis of these short term effects on plant and animal life. Further use of satellite imagery is required to permit better documentation of current land and estuarine uses and to develop optimum practices in the future.

One other area of concern, in terms of geological history, is that our climatic records are extremely short. Additional benchmark stations, at sites relatively unaffected by man-made modifications of any sort, are required to assure a continuum of basic data acquisition that will constitute authentic, correlative climatic records. A step in this direction is the recently authorized climatic benchmark station to be established in the near future in the vicinity of Jackson, Tenn., which will complement data from the other LMR benchmark station established in 1968 at the Calhoun Experiment Station near Calhoun, La. The importance of this program is brought into sharper focus when we consider

that geological records indicate past climate has varied cyclically over time, with glacial periods of 120,000 years long, and warm intervals of interglacial periods lasting about 12,000 years. Which way are we presently headed--have we reached our peak warming in this interlude and are we now advancing toward a new Ice Age?

Many of the data requirements for climatology have a parallel need in the meteorology field, and this is to be expected because much of our meteorological forecast techniques, the dynamic models, and the procedures utilized in the state and zone forecasts, the severe weather warnings, tornado, hurricane, and flood forecast models that serve the Lower Mississippi study area have been dependent to a very considerable degree on climate data.

There is a need for satellite imagery with a higher degree of resolution for severe weather and hurricane monitoring and forecasting. More sophisticated radars with improved rainfall intensity evaluation are a requirement, and research is essential for greater accuracy in quantitative precipitation forecasts. Automation of data acquisition networks, both for land and by offshore data buoys, is needed for timely acquisition of data that will permit prompt severe weather, tropical storm, and hurricane warnings to be issued. Additional tide gages as well as wave recorders for coastal areas and for inland bodies of water such as Lake Pontchartrain are definitely needed to furnish data for research and study leading to development of more accurate storm surge and storm tide forecasts for the coastal areas of the LMR study area.

As resources become available, regional studies need to be instituted in the field to better define the parameters, the orographic and geophysical or areal effects, and other pertinent factors that make up the "weather" in the Lower Mississippi Basin under similar synoptic and upper air systems. This is a requirement that takes resources but can definitely result in a better meteorological service to the public.

Ground Water

Ground water investigations are needed throughout the region to define accurately the potential yield of all aquifers. Although present ground water withdrawals in most areas can be increased, the practical limits of development must be determined for better planning and management. Reconnaissance studies are needed to better define the areal extent, hydraulic characteristics, potential yield, quality of water, and the effects of withdrawals on all aquifers. Detailed studies are needed in present and potential areas of large withdrawal to avoid the problems of local overdevelopment.

Studies are needed for a better understanding of the ground

water/surface water relationship to permit evaluation of the effects of the changing environment.

Changes in vegetation resulting from urbanization and land clearing for farming will directly affect the potential water yield in the region. The effects of these changes on evapotranspiration, infiltration, runoff, and ground water discharge need to be studied.

Some work has been done relating to the practicability of artificial ground water recharge to shallow aquifers. These studies should be expanded in scope to include all aquifers. Investigations should include methods of recharge by flooding as well as injection through wells.

Saline ground water in enormous quantities is available in the Lower Mississippi Region. Investigations to determine the potential yield of saline ground water should be continued in more detail in those areas where initial studies have been made and studies are needed for the remainder of the region. The feasibility of mixing saline and fresh water to increase the supply of potable water should be determined.

The Quaternary alluvial and terrace deposits warrant special attention as the primary source of ground water in the region, accounting for about two-thirds of the potential supply. The aquifers in the Quaternary deposits are adaptable to an annual cycle of withdrawal and replenishment. Withdrawals may be made up to the limit of the average annual recharge. Investigations are needed to define the recharge rate (including variations by area and conditions of precipitation), the effects of withdrawals on streamflow, and the effects on the ecology of the region.

Streamflow and Stage

The hydrologic data stations in the Lower Mississippi Region shown in figure 52 are used to obtain the stage and discharge information required for water resources planning and the development of projects required to solve water related problems. The network of gaging stations in the region is sufficient to furnish a key to the general coverage of hydrologic conditions over the entire region. However, additional stations are needed to more completely define the streamflow and runoff characteristics of many of the subbasins within the region. One of the greatest deficiencies in streamflow data is on the tributary streams with small drainage areas, most of which are located in the upper reaches of the main tributary streams. Runoff characteristics of both large and small basins should be gaged to define the low, mean, and peak flows under various climatologic and topographic conditions in the region.

Mean discharge data for monthly flows at streamflow gaging stations located throughout the Lower Mississippi Region are presented in this appendix. The average period for which discharge data were available for the stations is 25 years. It should be noted, however, that 19 stations had periods of record less than 15 years in length. This period was considered sufficient in computing frequency and duration data; however, a longer period of record is desired to obtain more reliable information. At several streamflow gaging stations located at or near the reservoir sites, a sufficient period of record of flow was not available for computing statistical data.

In order to achieve a better understanding of the principles of flow patterns in the coastal area, more streamflow gaging stations should be developed. Very few discharge stations are included in the coastal areas, and determination of mean flows generated within the coastal Water Resources Planning Areas was a particular problem in the preparation of data for this appendix.

The data collected at gaging stations where discharge records are obtained by use of a water-stage recorder and a stage-discharge relationship, combined with intermittent discharge measurements, are sufficient for use in computing peak flow and low flow frequency data and duration data. However, data collected at crest-stage gage and peak flow measurement stations are insufficient for computing low flow or duration data. In general, there was a definite lack of low flow data for gaging stations in many parts of the region, especially in the smaller drainage basins where changes in land-use patterns and climate could appreciably affect the low flows. The low flow frequency information is of particular importance in providing a basis for the design of water supply reservoirs, waste-disposal systems, for supplemental irrigation, and for fish and wildlife propagation.

The U. S. Geological Survey has originated a system of putting most of the records of daily discharge data in digital storage and computing specific statistical information from this data. Expansion of this system to include all of the streamflow and stage gaging stations within the Lower Mississippi Region would be a worthwhile task. Additional studies should be made using this data to determine the effect of climatic, topographic, and man-made changes on the streamflow characteristics of the major basins. The effect of changing land-use patterns, cultural practices, methods of watershed protection, and urbanization on the streamflow characteristics and natural basin runoff should also be evaluated.

More detailed studies of the effects of changes in streamflow patterns on the sedimentation of streams in the region should be made. The chief sources of erosion should be identified, and estimates of the quantities of sediment yields from each source should be derived. This information will be of great value in forming measures to reduce or

control sediment and erosion in streams and in the planning of future channel modification, flood control, and navigation projects.

Water Use

Adequate information on water use is basic in the planning and management of water resources in the region. The use of water has a pronounced effect on the supply and demand relationship because some of the various uses deplete the supply while others do not. The amount of water diverted from the streams is of great importance, but of equal importance is the amount of water which is returned directly or indirectly to the source of supply.

Inventories of the amount of water diverted from the streams and the amount consumed should be made by more systematic and standardized methods. The responsibility for the collection of the water-use data should be delegated to one agency to avoid misinterpretation of the data and duplication of effort.

Flow Velocity Studies

Few time of travel studies have been undertaken and completed on streams in the Lower Mississippi Region. Of those studies completed, results from streams in WRPA 7 are the only ones published to date. The remainder of the data were derived from preliminary sources. On some of the streams, the flow velocities were derived for rather high flows. The most important time of travel data should be derived for conditions of low flow.

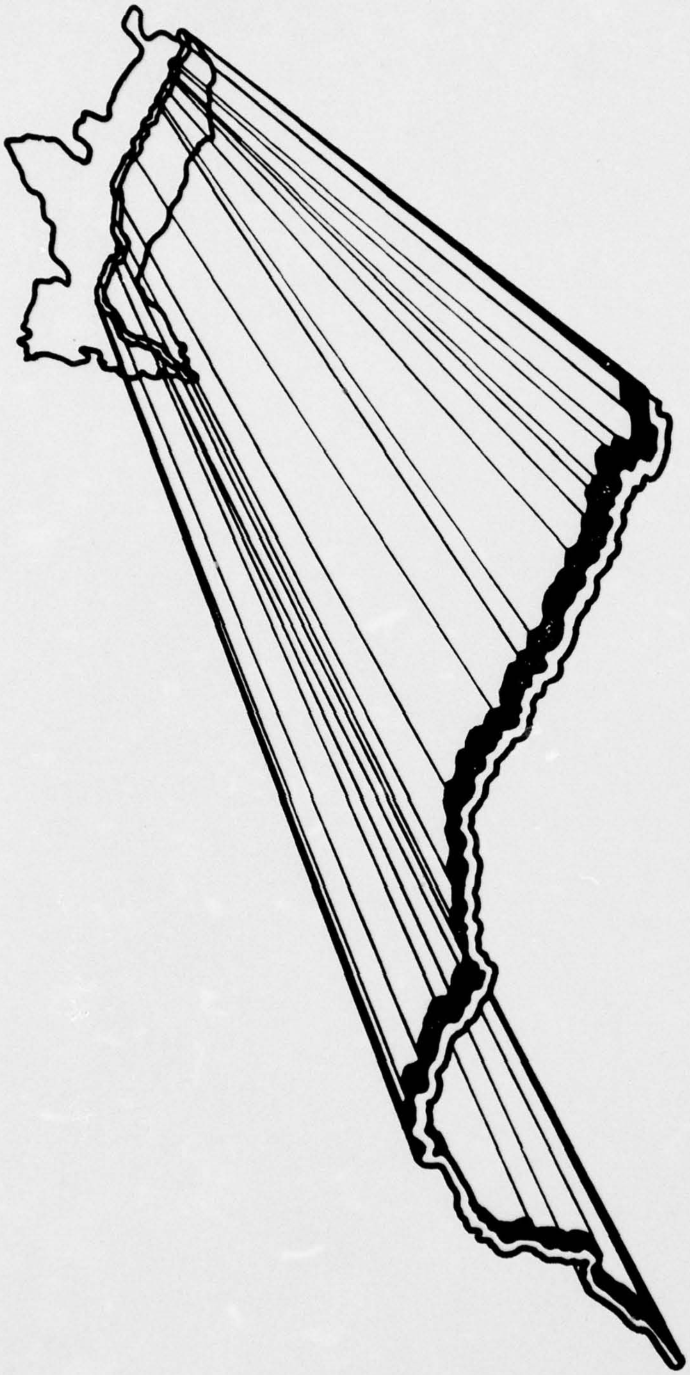
Time of travel information should be derived for the Mississippi River and all the main tributary streams. Investigations should also be undertaken on small streams which may be affected by pollution from any source. The time of travel studies should be made at various river stages and at various stations along the stream so that a realistic evaluation of the capacity of the stream to carry effluent at all ranges of flow can be established. Time of travel studies during periods of flooding would be useful in determining the effect that channel improvement projects have on stream velocities and times of concentration, and on peak flows generated in the basins.

Drainage Areas

One of the basic parameters in making a hydrologic study regarding low or flood frequency analysis, rainfall-runoff correlations, or design of structures to retard or control flows is the size of the drainage area of the basin being studied. The drainage areas of most of the streams in the Lower Mississippi Region are derived only at gaging stations along the streams, and can be obtained from stage or discharge publications printed by the Corps of Engineers and the U. S. Geological Survey. These drainage areas at the gaging sites, however, are not

always suitable for hydrologic studies on certain ungaged reaches of streams on which a project is to be considered.

In 1971, a publication entitled "Drainage Area of Louisiana Streams" was completed by the U. S. Geological Survey and the Louisiana Department of Public Works. The drainage area information presented in this publication is a great aid in alleviating the problems of establishing drainage areas mentioned in the preceding paragraph. Additional drainage area publications such as the above are needed to cover the remaining areas of the Lower Mississippi Region.



W R P A 1

W R P A 1

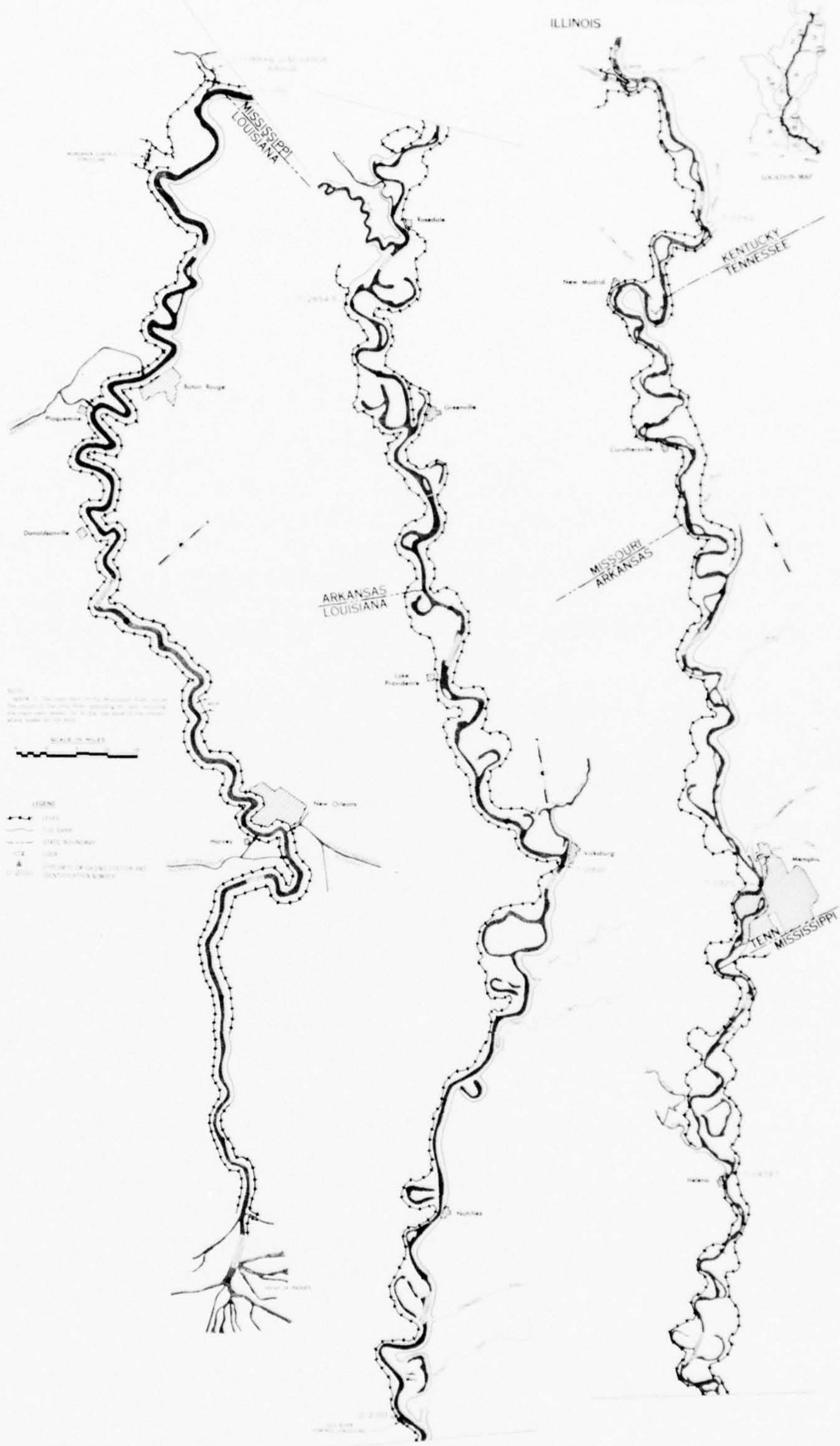
INTRODUCTION

WRPA 1 consists of the main stem of the Mississippi River from the mouth of the Ohio River to the Gulf of Mexico. It includes the main stem levees and extends to the top bank where no levees exist. WRPA 1 is composed of 2,435 square miles of land and water and occupies 2.4 percent of the Lower Mississippi Region. About 575 square miles, or 24 percent of the area, are covered with water and the remaining 1,860 square miles are land. The area is about 1,000 miles in length, averages less than 10 miles in width, and includes parts of seven states - Missouri, Illinois, Tennessee, Kentucky, Arkansas, Mississippi, and Louisiana. Elevations in the area within the levees or top bank vary from mean sea level in the area south of New Orleans, La., to above elevation 300 in the vicinity of Cairo, Ill. Figure 68 shows the WRPA boundaries, stream patterns, state lines, major cities, and other pertinent features of WRPA 1.

The entire area of WRPA 1 lies within the alluvial valley of the Mississippi River. This valley is a broad, gently sloping lowland which begins near the upper end of the region and extends to the Gulf of Mexico. This lowland varies in width from 30 to 125 miles and has an average width of 45 miles. Soils in the valley are truly alluvial from a geological point of view and consist mainly of sands and silts, grading progressively to very fine sands and silts in the lower portion of the area. Scattered through these sand and silt deposits are extensive deposits of clay. As is typical of streams flowing through alluvial valleys, the Lower Mississippi River has developed a highly sinuous course, creating numerous meander loops and bends. It has also shifted its channel from time to time so that parts of the alluvial plain have been reworked many times, thus contributing to the complexity of the soil structure of the area.

A well-defined characteristic of alluvial water courses is the formation of natural levees of heavy sediments near the stream banks. This results in drainage away from the stream to low ground near the valley walls, and bottomland drainage by streams running parallel to the main stream and joining it through major tributaries or at points where the main stream meanders close to the valley wall. This pattern of parallel drainage is well developed in the alluvial valley of the Mississippi River.

Another distinct physiographic feature of WRPA 1 is the Loess Hills which follow the Mississippi River from the vicinity of Cairo, Ill., to below Natchez, Miss. These hills, which are the results of aggradation



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

STREAMFLOW GAGING STATIONS

WRPA 1

FIGURE 68

of the soil by the forces of wind, can be recognized by their almost vertical bluffs.

The only stream in WRPA 1 is the Mississippi River. It rises near Lake Itasca in Minnesota and flows southward about 2,350 miles into the Gulf of Mexico. The river receives drainage from parts of two Canadian Provinces and 31 states, which makes the Mississippi River Basin the third largest drainage area in the world. This basin covers more than 1-1/4 million square miles or about 41 percent of the total land area of the 48 contiguous states of the United States [127]. The main stem Mississippi River channel below Cairo, Ill., carries runoff from about 922,000 square miles of drainage area concentrated at Cairo by the upper Mississippi and Ohio Rivers, and augmented by runoff from about 324,000 square miles of intervening drainage area between Cairo and the Gulf of Mexico.

Several major cities within the Lower Mississippi Region are located adjacent to WRPA 1. The economic development of these cities can be attributed in part to the development of the Mississippi River as a major inland waterway. New Orleans has become a major seaport for international trade and has a diversified industry associated with world trade. Baton Rouge is a major shipping and receiving port for crude oil and petroleum products by pipeline, sea-going vessels, and river barges. Between New Orleans and Baton Rouge, a major industrial area is expanding at a spectacular rate. Memphis, Tenn., is now noted as the largest industrial and transportation center between St. Louis and New Orleans, having excellent water-rail-highway terminal facilities. Industry in other major centers such as Natchez, Vicksburg, and Greenville, Miss., has been limited in general to the handling and processing of agricultural products and retail service establishments [128].

SURFACE WATER

Streamflow which is generated within WRPA 1 must originate either from precipitation on the surface of the Mississippi River or from run-off from the land areas between the channel and the levees or the top bank. The accurate measurement of this interior discharge is difficult to obtain due to the large volume of water which flows into the area from outside sources and flows through the area. Therefore, only the incoming flows to the area and the total flow discharged from the area were derived for this study. These flow values are presented in the following section.

Quantity

The mean annual discharge at the mouth of the Mississippi River is about 453,000 c.f.s. This flow constitutes about 68 percent of the total flow discharged in the Lower Mississippi Region. An additional flow averaging about 120,000 c.f.s. is diverted from the Mississippi through the Old River Control Structure to the Atchafalaya River.

Inflow into WRPA 1 from other areas occurs at intervals along the Mississippi River from Cairo, Ill., to the Gulf of Mexico. The major portion of inflow into the area is from the Ohio and Upper Mississippi Rivers, which contribute a combined mean annual flow of about 452,000 c.f.s. into the area. Additional inflows from the White, Arkansas, and Red Rivers total about 25,000, 40,000, and 31,000 c.f.s., respectively.

Present Utilization

One of the United States' greatest industrial attractions is the Mississippi River, whose water has become so important to industry that it is now regarded as an indispensible raw material for both processing purposes and transportation of products. Port and terminal facilities along the Mississippi River are rapidly expanding to handle increased river commerce. Large quantities of cooling and processing water are being withdrawn by the basic metal and petrochemical industries which are still growing rapidly in the Baton Rouge to New Orleans, La., area.

Water for major agricultural uses and for irrigation is currently supplied from wells, local impoundments, and nearby lakes and streams. There are no significant agricultural or municipal diversions from the main stream Mississippi River, and no large scale diversions are expected in the near future.

The main stem of the Mississippi River, together with lakes, bayous, and tributary streams within the main stem floodway, supports a substantial commercial fishing and wildlife habitat. Timbered areas in

the main stem floodway support game which provides substantial employment for commercial trappers and guides. The coastal plains area supports widespread employment in oyster fisheries and commercial trapping of muskrats. These are both dependent to a large extent on the control of salinity and silt movement in the coastal region. The Mississippi River is also used by vacationists from all parts of the nation for fishing, boating, and water sports during the summer months.

Withdrawals and utilization of surface water sources in WRPA 1 from the Mississippi River during 1970 were allocated to the adjacent Water Resources Planning Areas for publication in this report. Therefore, no water use data are presented in this section.

Stream Management

The Mississippi River, without question America's greatest river, has made major contributions to the physical and economic growth of the nation. As a navigation artery, it is of great importance to the commerce of the nation. It is the chief supply of water for many industries located along its banks. The Mississippi is one of the United States' most outstanding assets and this is being emphasized more and more as the nation continues to grow. Uncontrolled, the river could be a great liability. For these reasons, an effective system of stream management in WRPA 1 on the Lower Mississippi River is essential.

Flood control. A comprehensive plan of stream management is in effect to provide flood protection for a large part of the alluvial valley of the Mississippi River. This flood-control plan involves the blending of a number of features including levees for containing flood flows, floodways for the passage of excess flows past critical reaches of the Mississippi River, channel improvement and stabilization to increase the flood-carrying capacity of the river, and tributary basin improvements for major drainage and flood control through use of dams, pumping plants, auxiliary channels, and other forms of flood protection.

The project design flood. A study was initiated in 1956 to determine maximum flow lines for which flood-control elements along the Mississippi River should be designed. Several combinations of severe storms in the tributary basins were studied and their position, sequence, intensity, and runoff factors were modified to produce the maximum associated runoff in the Mississippi River. Of the four hypothetical sequences selected for final study, the one which produced the maximum unregulated discharge at all key stations below the Ohio River was considered as the best estimate of the largest flood in the Lower Mississippi River for which protection should be provided.

The unregulated flows at key stations in tributary basins were modified then routed through the stream system in accordance with the planned operation of existing and prospective reservoirs to determine the

approximate cumulative effect that the reservoirs have on flow in the main stem.

The study considered a group of 107 reservoirs then existing or under construction designated as "Group E," and an additional group of 44 others designated "Group EN" whose future construction was reasonably certain.

The hypothetical flood which produced the largest unregulated flow at key stations on the main stem also produced the largest flood both with and without regulation, and was therefore selected, with "Group EN" reservoirs operating as the project design flood. The profile of the project design flood is shown in figure 89 and the associated peak discharges are shown in figure 69, a schematic diagram of the project design flood. The various diversions of flow through floodways which are to be operated during the project design flood or any other severe flood are also shown in figure 69.

Levees. The main stem levee system, consisting of levees, floodwalls, and various control structures, will be about 2,200 miles in length upon completion. About 1,600 miles lie adjacent to the Mississippi River and 600 miles lie along the south banks of the Arkansas and Red Rivers and in the Atchafalaya Basin. To date, about 1,550 miles of levee have been completed.

As a result of many years of work, the Mississippi River has been effectively confined between the levees. The levee line on the west bank begins south of Cape Girardeau, Mo., and, except for structurally controlled gaps where the St. Francis and the Arkansas-White Rivers join the Mississippi, extends unbroken to the Gulf of Mexico. There are navigation locks through this levee line at Port Allen, La., at two locations near New Orleans, and at Empire, La. On the east bank of the river, levees alternate with high bluffs to provide flood protection for areas between Cairo and the Gulf.

Floodways. If the carrying capacity of the leveed channel of the Mississippi River is exceeded during a major flood, relief outlets through the Birds Point-New Madrid Floodway, Atchafalaya Basin, and Bonnet Carre Floodways are utilized along with the storage capacity of flat lowlands at junctions of Mississippi's major tributaries. These backwater areas serve as reservoirs to store water during floods. They are usually protected from lesser floods by interior levee systems that are designed to be overtopped by major floods. A schematic diagram of the floodways showing their capacity in passing the project design flood is presented in figure 69.

The east bank bluffs and the levees on the west bank of the Mississippi River between Cairo, Ill., and New Madrid, Mo., form a narrow channel through which the river must flow at high stages. To protect

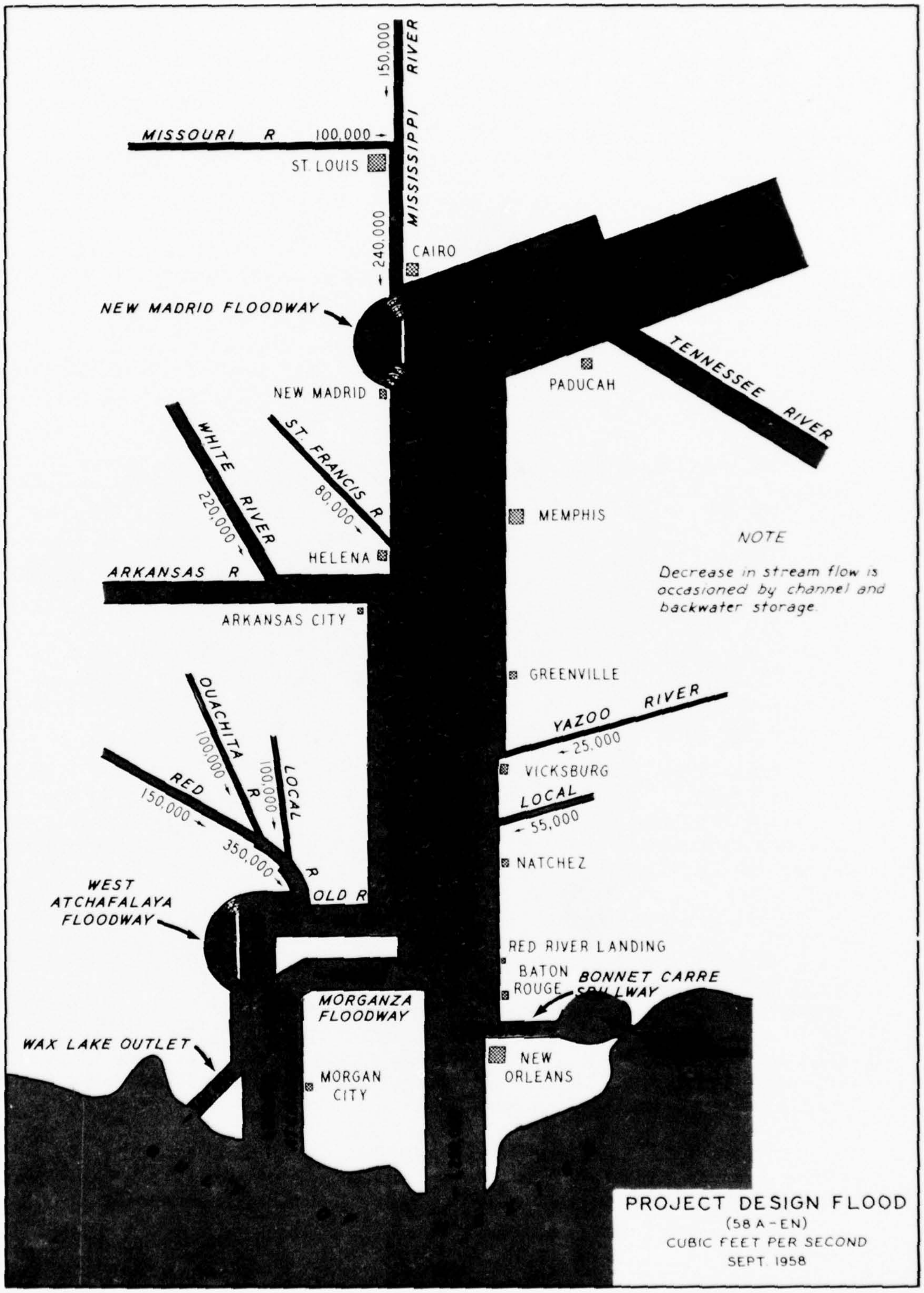

150,000
MISSISSIPPI RIVER
MISSOURI R
100,000
ST. LOUIS
240,000
CAIRO
NEW MADRID FLOODWAY
NEW MADRID
PADUCAH
TENNESSEE RIVER
WHITE RIVER
220,000
ST. FRANCIS R
80,000
MEMPHIS
HELENA
ARKANSAS R
ARKANSAS CITY
NOTE
Decrease in stream flow is occasioned by channel and backwater storage.
GREENVILLE
OUACHITA R
100,000
LOCAL
100,000
YAZOO RIVER
25,000
VICKSBURG
RED
150,000
LOCAL
55,000
350,000
R
NATCHEZ
WEST ATCHAFALAYA FLOODWAY
OLD R
RED RIVER LANDING
BATON ROUGE
BONNET CARRE SPILLWAY
MORGANZA FLOODWAY
WAX LAKE OUTLET
NEW ORLEANS
MORGAN CITY
PROJECT DESIGN FLOOD
(58 A-EN)
CUBIC FEET PER SECOND
SEPT. 1958

FIGURE 69

the city of Cairo and reduce flood heights, a setback levee was built about 5 miles west of the riverfront levee. The strip of land between the setback levee and the levee adjacent to the river forms the Birds Point-New Madrid Floodway (figure 69). At extremely high stages, water enters the floodway through fuseplugs at Cairo and reenters the main river above New Madrid. The floodway was operated only in 1937 and was of great aid in reducing flood heights at and above Cairo.

From the latitude of Red River Landing, the project flood is conveyed to the Gulf of Mexico via the Mississippi and Atchafalaya Rivers with each carrying approximately one-half of the total flow. Of the portion remaining in the main Mississippi Channel below Morganza Floodway, roughly one-sixth is diverted to Lake Pontchartrain and the Gulf of Mexico through the Bonnet Carre Spillway located about 25 miles above New Orleans, La. The Bonnet Carre Spillway was operated in 1937, 1945, 1950, and 1973.

That portion of the flow diverted from the Mississippi River is carried by the Atchafalaya River and West Atchafalaya Floodway (along with flow from the Red River), and by the Morganza Floodway. The West Atchafalaya Floodway is controlled by a fuseplug levee at its head and the Morganza Floodway is controlled by a gated spillway in the Mississippi River levee near Morganza, La. The Morganza and West Atchafalaya Floodways follow down on opposite sides of the Atchafalaya River until the end of the levee system along the Atchafalaya River is reached; there they merge into a single broad floodway that passes the flow to the Gulf through two outlets, Wax Lake and Berwick Bay. The West Atchafalaya Floodway has not been used. The Morganza Floodway was used in 1973 for the first time.

Channel improvement and stabilization. Work to improve and stabilize the channel of the Mississippi River consists of cutoffs to shorten the river and reduce flood heights, revetment to curtail the river's tendency to meander, dikes to direct flows in the channel, and dredging to realine the channel.

By 1942, a total of 16 cutoffs and two major chutes had been developed. It is estimated that these improvements, when made, lowered river stages about 16 feet at Arkansas City, Ark., and 10 feet at Vicksburg, Miss. These cutoffs are still intact and effective; however, channel efficiency has since diminished, raising stages by 2 to 3 feet. This is due primarily to the instability introduced by the cutoff program and the persistent tendency of the river to meander. The 16 cutoffs have reduced the river distance from Memphis, Tenn., to Baton Rouge, La., by about 114 miles [122].

An important aspect of the Mississippi River flood-control and navigation plan is the stabilization and protection of the riverbanks. Many types of protective works including willow, lumber, and asphalt

mattresses, have been used in the past. To date, the most economical and effective means of protecting the banks from caving and erosion is revetment composed of an articulated concrete mattress underwater and stone or riprap paving above the water. The concrete mattress and stone paving are both placed on graded bank. As of June 1970, revetment of the banks of the Mississippi River had extended to over 610 miles in length [122].

Dikes are used to regulate or contract the width of the Mississippi River channel during periods of low water and direct the channel into a favorable alinement. The dikes, constructed of timber piling and riprap or crushed stone, are usually placed in the convex part of bends where the channel crosses to the opposite shore. They are also used to assist in the closing of secondary channels and chutes. To date, about 115 miles of dikes have been constructed on the Mississippi River [122].

Dredging is employed on the Mississippi River to complete the permanent alinement of the channel and to clear away remaining obstructions in the channel to maintain a low water navigation channel 9 feet in depth and 300 feet in width. Cutterhead, dustpan, and hopper type dredges are used to dig and remove material from the channel and discharge it through long pipelines to deposit it away from the channel or wherever it is needed for filling dike fields or closing secondary channels.

Results of flood-control works. The effectiveness of completed flood-control works on the Mississippi River has been demonstrated on several occasions as attested by the successful operation of the Bonnet Carre Spillway (figure 69) during the 1945 flood. The peak discharge of the 1945 flood at Red River Landing was only 10 percent less than the estimated peak discharge of the 1927 flood at the same latitude. The 1927 flood, considered to be the greatest flood to occur in the Lower Mississippi Valley, inundated about 26,000 square miles, killed 214 persons, and resulted in property damage of 236 million dollars, which is equivalent to more than one billion dollars today. A repeat of that disaster would have been likely in 1945 in the absence of flood-control improvement. However, the Bonnet Carre Spillway was operated to provide protection for the city of New Orleans, and all of the main line levees held and greatly reduced the potential damage to property, crops, and human lives.

Another flood occurred on the Lower Mississippi River in 1950 when damage estimated at about 6.6 million dollars occurred in unprotected backwater areas. Those damages would have been nearly 20 times greater had not the main line levees and completed tributary works been in operation. Since 1928, the flood-control works within the Lower Mississippi Valley have prevented flood damage in excess of 8.5 billion dollars and have resulted in a vast amount of intangible benefits such as prevention

of loss of life and promotion of health, welfare, and security of the citizens of the alluvial valley [122].

Navigation. Navigation along the Mississippi River is one of the more important uses of water in the Lower Mississippi Region. The Mississippi River is the main stem of the network of inland navigable waterways which form a water transportation system of about 12,350 miles in length, not including the 1,173 miles of Gulf Intracoastal Waterway or its connecting inland and Gulf Coast streams. This giant system of waterways includes the Ohio, Missouri, Illinois, Arkansas, and Tennessee Rivers and extends to the midwest and the industrial east. Heavy commercial traffic includes grain, coal, petroleum products, nonmetallic minerals, metal products, building materials, sand and gravel, salt, sulphur, chemicals, and various other products. Also, many pleasure craft from all parts of the nation now use the Mississippi River for vacation, travel, and water sports [132].

Currently, a navigation channel of 9-foot depth and 300-foot width is maintained on the Mississippi River between Cairo, Ill., and Baton Rouge, La. The development of a navigation channel for oceangoing traffic in the reaches below Baton Rouge was authorized in 1945. Current depths and widths of the channel between Baton Rouge and New Orleans are about 40 and 500 feet, respectively. From New Orleans to Head of Passes, the channel is about 40 feet in depth and 1,000 feet wide. Depths of the various passes range from 30 to 40 feet and channel widths from 450 to 800 feet.

The navigation depths are maintained in the Lower Mississippi River by dredging. The navigable channel consists of a series of pools interrupted by bars or crossings which occur where the stream current crosses from one side of the channel to the other and deposits sand in the form of bars. The variable depths of the river at these crossings determine the available navigation depths. The number of crossings dredged and redredged and the amount of dredging required in any one low water season depend largely upon the duration of the low water season and frequency of stage fluctuations during the low water season. These factors directly affect the stability of dredge cuts in the river's sandy bed. The dredging required to maintain the 9-foot channel between Cairo and Baton Rouge ranges from 30 to 70 million cubic yards per year [132]. Dustpan-type dredges move most of the sandy material, and large cutterhead-type dredges are used to remove compacted clay or gravel.

Streamflow

Various periods of record of flow data are presented in this section because of the availability of discharge data at the selected sites. For each discharge station selected, the period of record provides reasonably good data for statistical analysis and study in this appendix, and the data are considered to be representative of flows which could occur under 1973 levels of development.

Measurement facilities. Streamflow data at eight stations along the Mississippi River and Old River were selected for presentation in this section. Locations of these stations are shown in figure 68, a map of WRPA 1, and are identified by U. S. Geological Survey station numbers. Table 24, a summary of the streamflow data at each of the selected sites, presents such data as the controlling agency, the drainage area, period of record, gage datum, extreme flows, and other pertinent hydrologic data at each site.

Table 24 - Streamflow Summary for Selected Sites, WRPA 1

Stream	Station	Agency	Station No.	Gage Datum (feet m.s.l.)	Drainage Area (square mile)	Period of Record	Annual Flows (1,000 c.f.s.) Mean	Maximum	Minimum	Momentary Maximum Flow (1,000 c.f.s.)	Daily Minimum Flow (1,000 c.f.s.)	Stage Data (feet m.s.l.) Highest	Lowest
Mississippi River	Hickman, Ky.	CE	7-0242	264.73	922,500	1945-70	452	656	253	2015 1/	69 2/	316.2	264.3
Mississippi River	Memphis, Tenn.	GS	7-0320	183.91	932,700	1945-70	470	679	263	2020 1/	78 2/	232.6	178.6
Mississippi River	Helena, Ark.	CE	7-0479.7	141.70	941,700	1945-70	480	708	269	2041 1/	81 2/	201.9	138.7
Mississippi River	Arkansas City, Ark.	CE	7-2654.5	96.66	1,108,560 9/	1929-70	534	815	264	2159 3/	88	155.9	91.4
Mississippi River	Vicksburg, Miss.	CE	7-2890	46.23	1,122,160 9/	1927-70	553	844	272	2064 4/	94	99.5	39.2
Mississippi River	Tarbert Landing, Miss. 5/	CE	01100	0.00	1,128,900	1938-70 5/	453	767	243	1977	85	58.1	4.7
Lower Old River	Torras, La.	CE		1.11		1938-63 6/	112	188	-21 8/	519	-316 8/	61.6	3.3
Old River Outflow Channel	Knox Landing, La.	CE	02100	0.00	1,128,700	1963-70 6/	120	164	61	390	0 7/	47.8	1.32

1/ Discharge not determined for record high gage reading.
2/ Discharge not determined for record low gage reading.
3/ 2,472,000 cfs if 1927 flows had been confined between the levees.
4/ 2,278,000 cfs if 1927 flows had been confined between the levees.
5/ Discharge at Red River Landing, La., prior to 12 July 1963.
6/ Discharge at Lower Old River at Torras, La., prior to 12 July 1963 (date of closure of Lower Old River) and at Old River outflow channel near Knox Landing, La., since then.
7/ With gates closed on Old River Control Structure.
8/ Flow toward Mississippi River.
9/ Adjusted for 22,240 square miles of noncontributing area.

Average discharge for WRPA 1. A reliable value for the average discharge generated within WRPA 1 was difficult to derive due to the tremendous volume of water which flows through the area. For this reason, values of the monthly streamflow discharged through the area are given instead of a discharge generated specifically within the area. Streamflow data measured at the Tarbert Landing, Miss., discharge range are shown by graphical representation in figure 70. This figure also presents the maximum and minimum flows as well as the mean monthly flows. The flows at this point are considered to be representative of flows discharged at the mouth of the river because very little inflow enters the main channel below the discharge station.

Average discharge for selected stations. Detailed hydrologic data at each of the eight selected gaging stations shown in table 24 are presented in this section. Tables 25 through 32 present observed mean discharges by months for each of the selected sites in WRPA 1. Also shown in these tables are the average monthly and average annual flows for the period of record at each station. These flows reflect regulation and use under 1973 levels of development in the area.

Frequency curves for peak flows at the selected gaging stations in

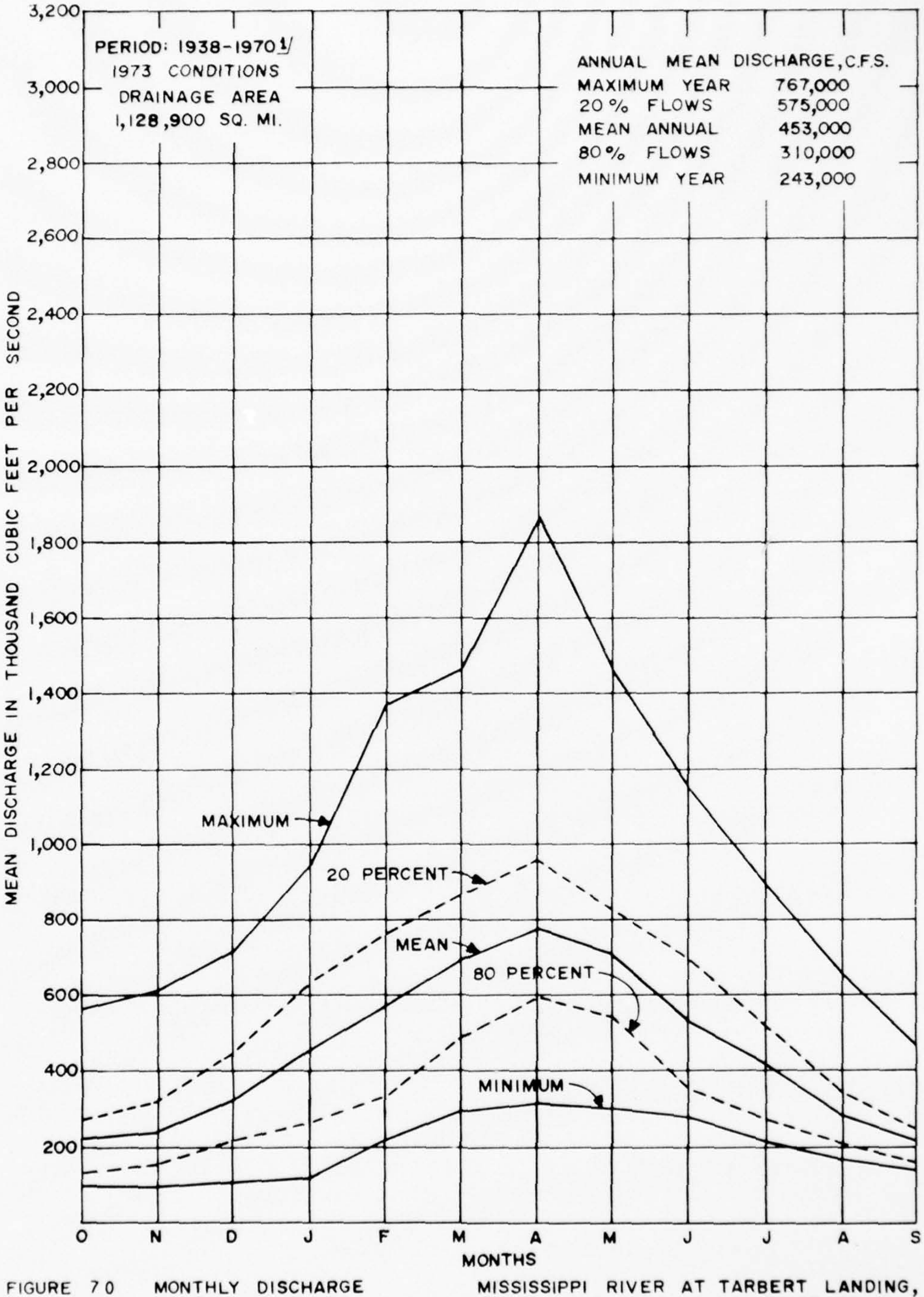


FIGURE 70 MONTHLY DISCHARGE
STATION NO. O-1120

MISSISSIPPI RIVER AT TARBERT LANDING, MISS.
1/RED RIVER LANDING, LA., PRIOR TO JULY, 1963

WRPA 1 are shown in figures 71 through 75. These curves are a reflection of the annual peak discharges at the sites and were computed using the standard method of the Corps of Engineers [6].

Low flow frequency curves at the selected sites are shown in figures 76 through 81. These curves represent the lowest mean flows for periods ranging from 3 to 160 consecutive days at certain sites.

Duration curves for daily flows at the selected sites in WRPA 1 are presented in figures 82 through 87. These curves show the percent of time that specified discharges were equaled or exceeded at the sites during given periods. The curves indicate flow characteristics of the streams throughout their entire range of discharges without regard to the sequence of occurrences. The maximum daily flows at the sites are listed on the curves because of the lack of space required to extend the curves to the zero percent exceedence point.

Data on the dependable yield characteristics at each of the selected discharge sites are presented in tables 33 through 38. These tables show the lowest mean flows for from 1 to 10 consecutive years of the period of record. The relationship of these flows to the mean flows for the period of record is also shown. The minimum annual flow for stations in WRPA 1 ranged between 49 and 56 percent and averaged 53 percent of the mean annual flow. For the 10 consecutive years of lowest mean flow, the average flows were about 90 percent of the mean annual flows at the gaging stations.

Variations in precipitation and discharge. Long-term variations in discharge in WRPA 1 are caused chiefly by long-term variations in rainfall and snowfall in the tributary streams of the Upper Mississippi River. Shown in figure 88 is a comparison of the precipitation at Vicksburg, Miss., and the discharge of the Mississippi River at Vicksburg. The mean and 5-year moving averages of both precipitation and discharge are shown to better illustrate the general trend of long-term changes in precipitation and discharge. This figure is not intended to show a definite correlation between precipitation and discharge at the site due to the large drainage area of the Mississippi River above Vicksburg. However, the curves do indicate to some degree that changes in precipitation trends at Vicksburg have some effect on flows of the Mississippi River at Vicksburg. This is due to the fact that the precipitation trends at Vicksburg usually coincide with general precipitation trends in the area's tributary to the Lower Mississippi River above Vicksburg. Hence, the precipitation curve tends to illustrate the general trends of precipitation not only at Vicksburg but also in areas above Vicksburg which contribute to flows in the Mississippi River.

Seasonal variations in streamflow of the Mississippi River are evident in the observed mean flows given in tables 25 through 32. The major flows usually occur during the months of March and April. This

tends to melt the snow in the upper areas. The spring rains usually yield a large percentage of runoff which flows through tributary streams directly to the Mississippi River.

Flow Velocities

A time of travel study was made on the Mississippi River from Baton Rouge to New Orleans, La. Travel times were measured from dye tracings for a flow of 240,000 c.f.s., which is equaled or exceeded over 70 percent of the time. These data were used to compute average velocities in the subreaches. Hydrographic surveys were used on the Mississippi River near Rosedale and Vicksburg, Miss., to determine average velocities in that reach of the river.

The velocities, which are shown in figure 53, correspond to a specific discharge, and, since velocity varies with discharge, the user should be cautious in applying these data to any other condition of flow. In general, stream velocities vary with discharge so that at higher discharges, greater velocities would be expected. The velocities represent the average velocity through a subreach; however, velocities can vary from point to point within a subreach. The velocities given for WRPA 1 were derived from preliminary studies and are subject to revision upon completion of more detailed studies.

River Profile

A profile of the Mississippi River from Cairo, Ill., to the Gulf of Mexico via Southwest Pass, as shown in figure 89, was constructed from topographic maps, hydrographic surveys, and data from available reports [136]. The profile shows the 1962-64 thalweg of the river, the average low water plane, the 1937 and 1927 highwater profile, and the Project Design Flow Line. The Project Design Flood was used to establish the required levee grades. Major stations are also shown, along with maximum and minimum discharges at the respective stations. A chart which shows pertinent data at each of the stage stations is presented. The highest and lowest stages, bankfull stages, and the average low water plane are tabulated.

Quality

Surface water in WRPA 1 is suitable for both industrial and municipal uses.

Chemical quality data collected on the Mississippi River near St. Francisville, at Luling Ferry, and New Orleans, La. (table 39), indicate that daily variations in chemical quality are small. In addition, a recent survey was made on the Lower Mississippi River, and the results indicate that the chemical quality of water in the Mississippi River changes very little from the Arkansas State line (mile 505) to Baton Rouge (mile 236). In the reach of the river between Baton Rouge (mile

236) and Belle Chasse (mile 76), the water becomes more mineralized (from about 300 to 360 mg/1 of dissolved solids). Chemical constituents accounting for most of this increase were chloride, sulfate, sodium, and calcium, with chloride increasing from 28 to 47 mg/1. The increase was due to industrial and municipal waste effluents. The Mississippi River receives about 20,000 tons per day of inorganic waste and about 500 tons per day of organic wastes from industrial and municipal complexes located along the river from St. Francisville to New Orleans, La. Industrial discharge of inorganic waste has little effect on water quality during high flows; however, during low flow periods the effects are significant. Organic wastes discharged into the Mississippi River between Baton Rouge and New Orleans decrease the dissolved-oxygen concentration about 1.0 mg/1, with the largest decrease occurring during summer and low flow periods. In addition, great quantities of acidic waste are assimilated each day with very little effect on the river.

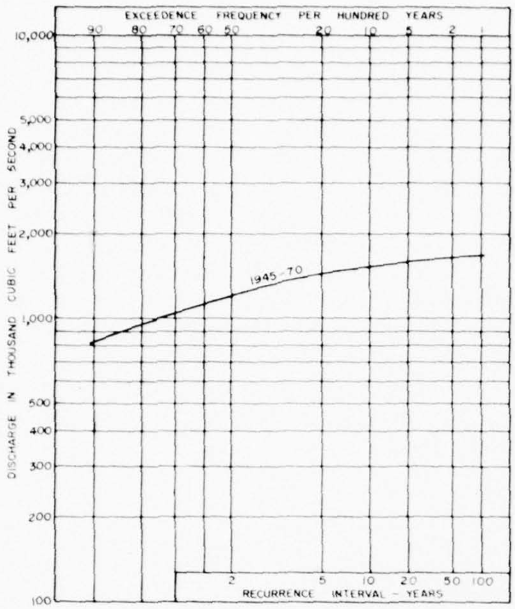


FIGURE 71 FREQUENCY CURVE OF ANNUAL PEAK FLOWS
7-0242 MISSISSIPPI RIVER AT HICKMAN, KY.

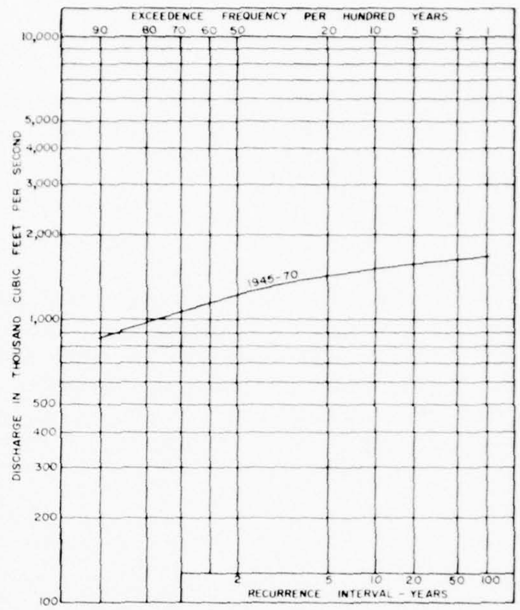


FIGURE 72 FREQUENCY CURVE OF ANNUAL PEAK FLOWS
7-0320 MISSISSIPPI RIVER AT MEMPHIS, TENN.

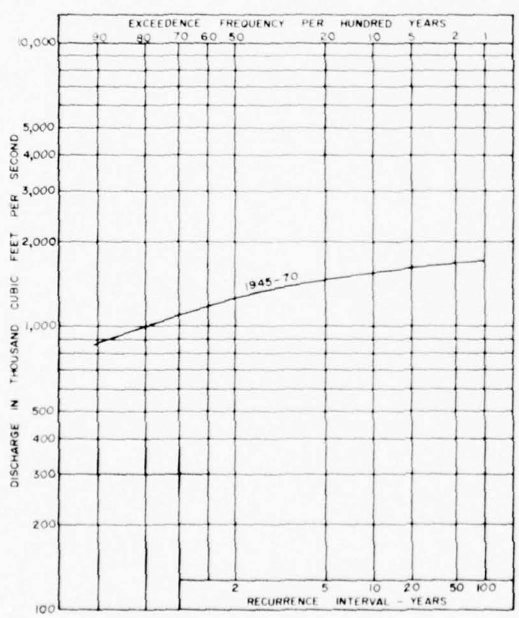


FIGURE 73 FREQUENCY CURVE OF ANNUAL PEAK FLOWS
7-0479.7 MISSISSIPPI RIVER AT HELENA, ARK.

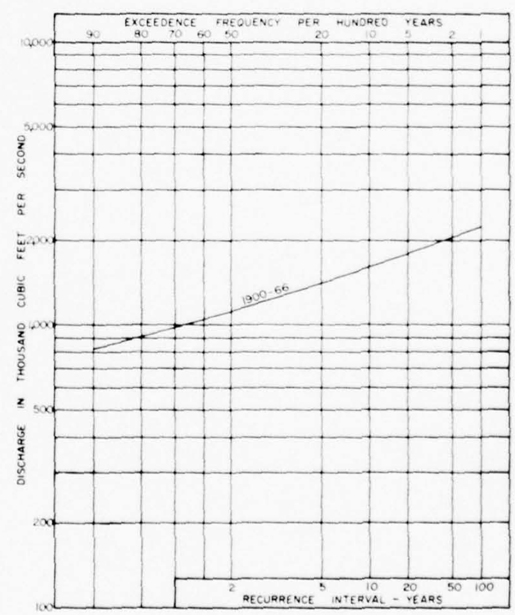


FIGURE 74 FREQUENCY CURVE OF ANNUAL PEAK FLOWS
7-2890 MISSISSIPPI RIVER AT VICKSBURG, MISS.

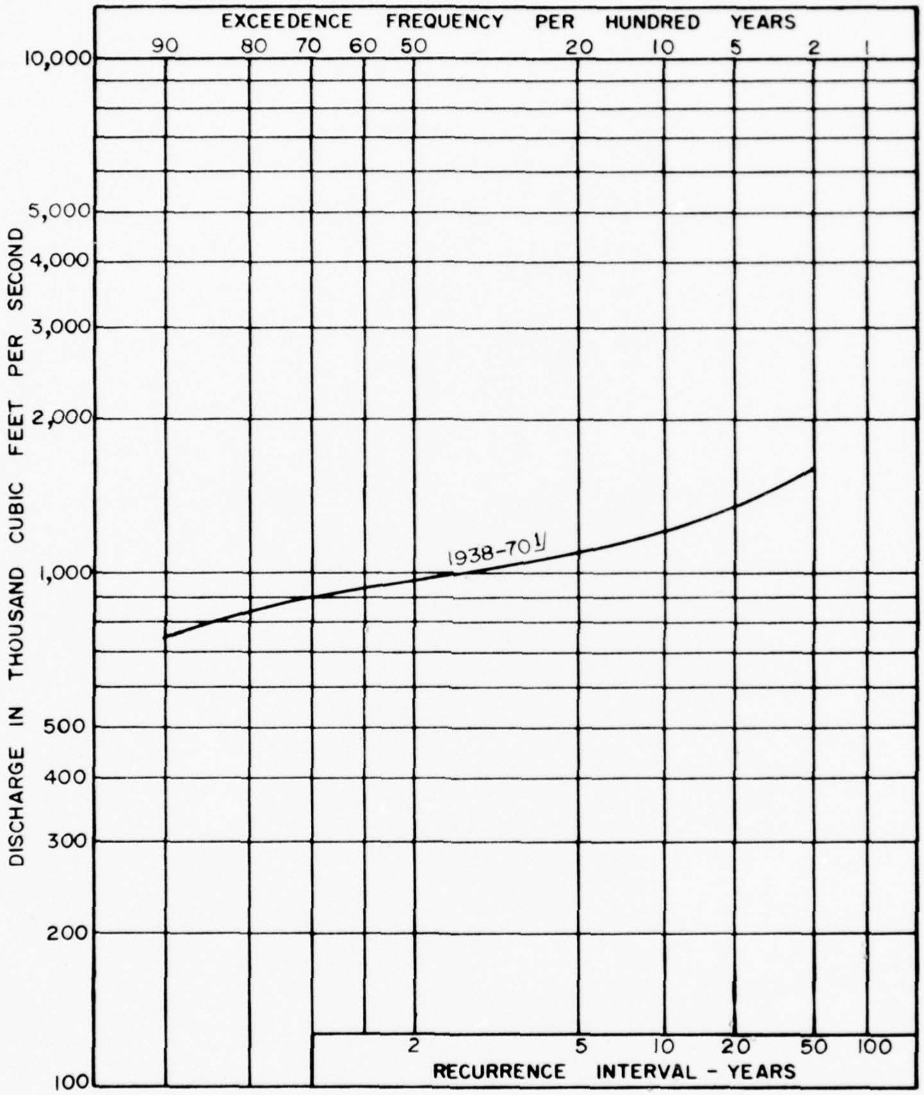


FIGURE 75 FREQUENCY CURVE OF ANNUAL PEAK FLOWS
0-1120 MISSISSIPPI RIVER AT TARBERT LANDING, MISS.

1/ RED RIVER LANDING, LA. PRIOR TO JULY, 1963

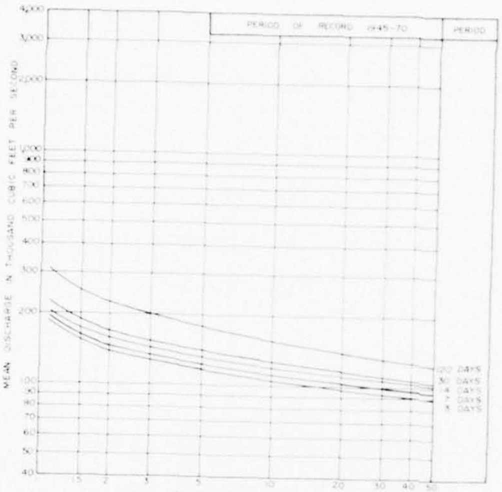


FIGURE 76 LOW FLOW FREQUENCY CURVES
7-0242 MISSISSIPPI RIVER AT HICKMAN, KY

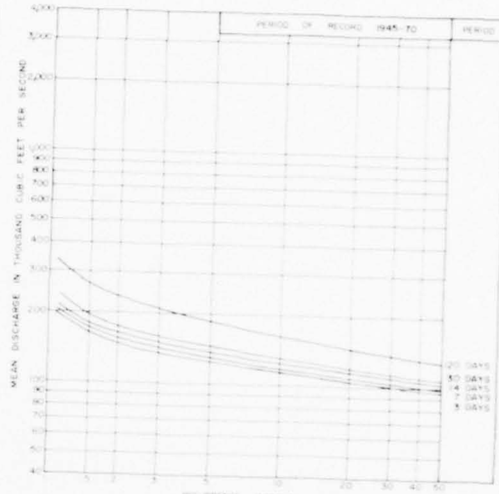


FIGURE 77 LOW FLOW FREQUENCY CURVES
7-0320 MISSISSIPPI RIVER AT MEMPHIS, TENN

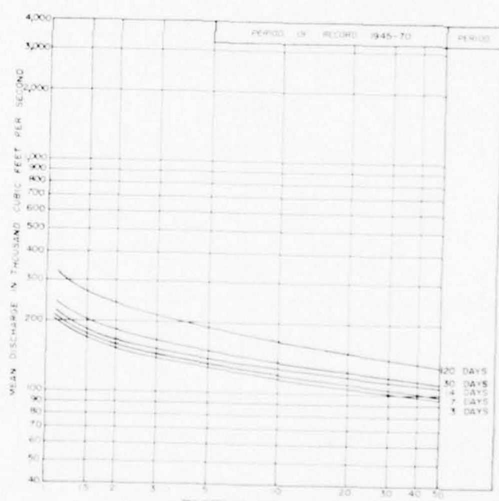


FIGURE 78 LOW FLOW FREQUENCY CURVES
7-04797 MISSISSIPPI RIVER AT HELENA, ARK.

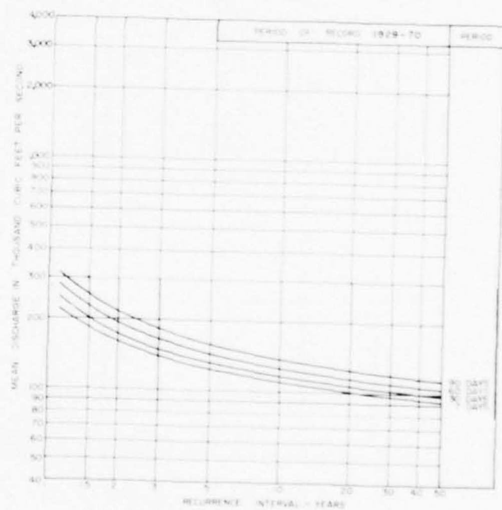


FIGURE 79 LOW FLOW FREQUENCY CURVES
7-2654.5 MISSISSIPPI RIVER AT ARKANSAS CITY, ARK.

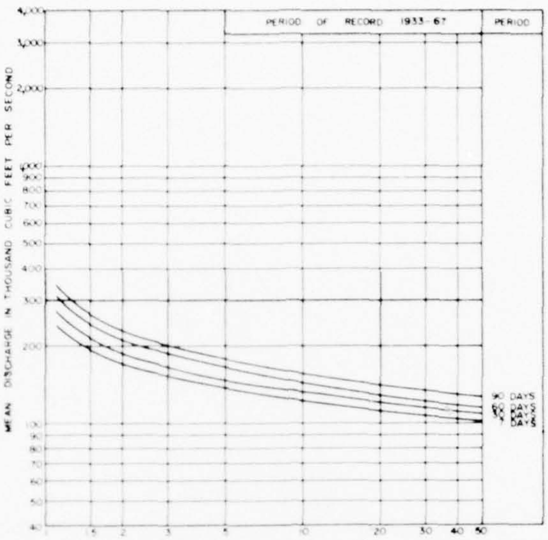


FIGURE 80 LOW FLOW FREQUENCY CURVES
7-2890 MISSISSIPPI RIVER AT VICKSBURG, MISS

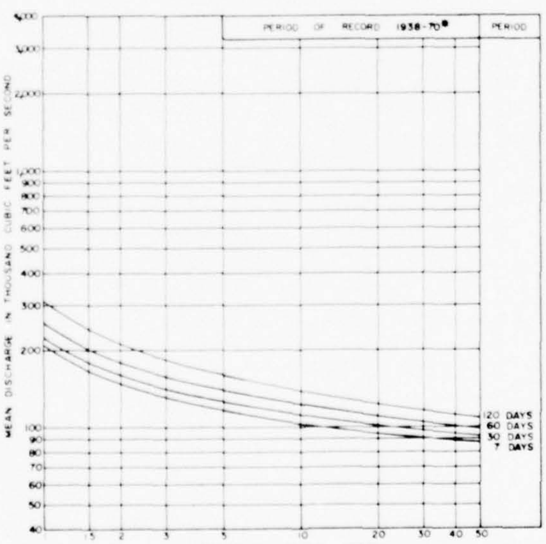


FIGURE 81 LOW FLOW FREQUENCY CURVES
0-1120 MISSISSIPPI RIVER AT TARBERT LANDING, MISS
*RED RIVER LANDING, LA., PRIOR TO JULY 1963

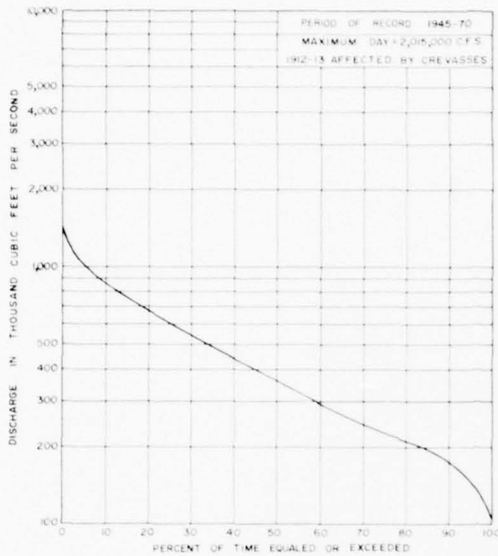


FIGURE 82 DURATION CURVE
7-0242 MISSISSIPPI RIVER AT HICKMAN, KY.

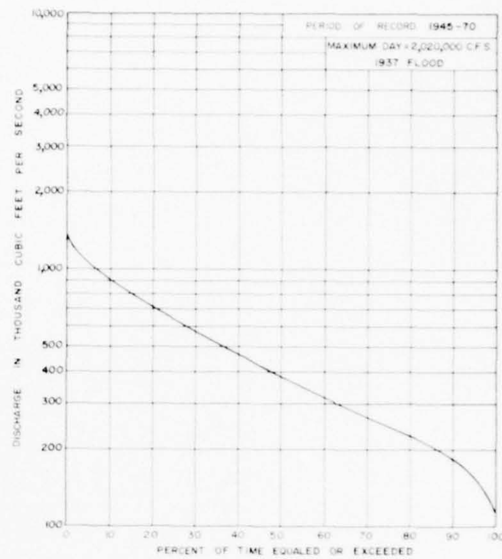


FIGURE 83 DURATION CURVE
7-0320 MISSISSIPPI RIVER AT MEMPHIS, TENN.

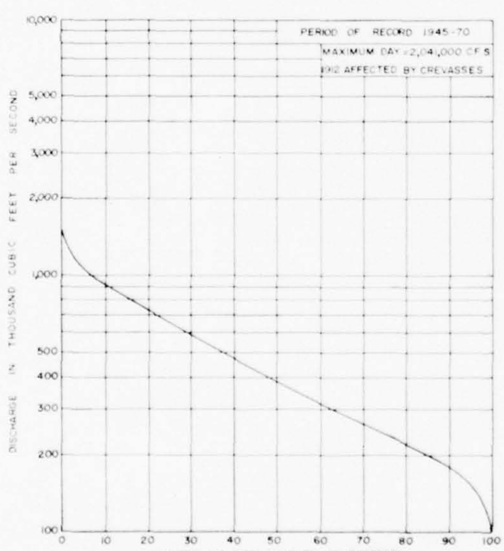


FIGURE 84 DURATION CURVE
7-0479.7 MISSISSIPPI RIVER AT HELENA, ARK.

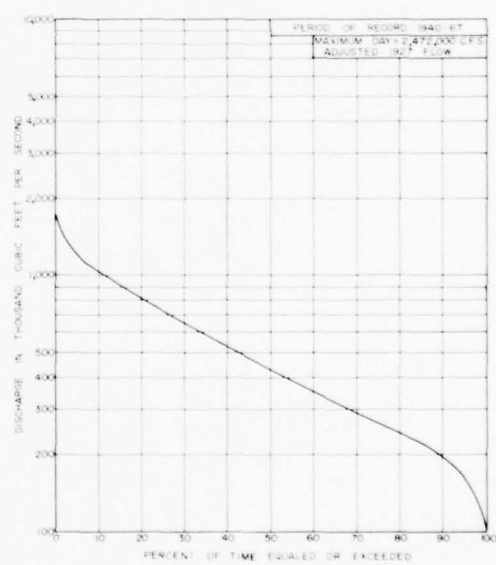


FIGURE 85 DURATION CURVE
7-2654.5 MISSISSIPPI RIVER AT ARKANSAS CITY, ARK.

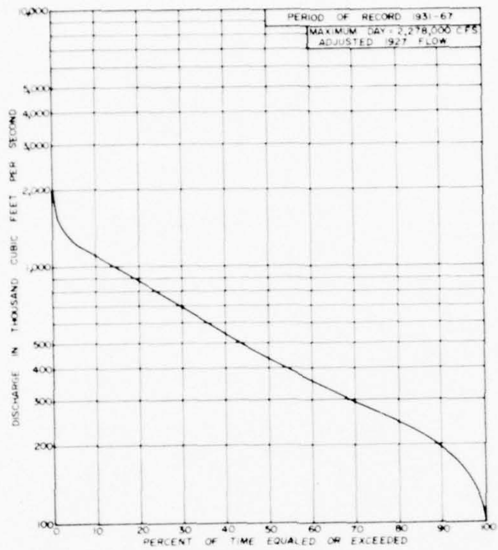


FIGURE 86 DURATION CURVE
7-2890 MISSISSIPPI RIVER NEAR VICKSBURG, MISS.

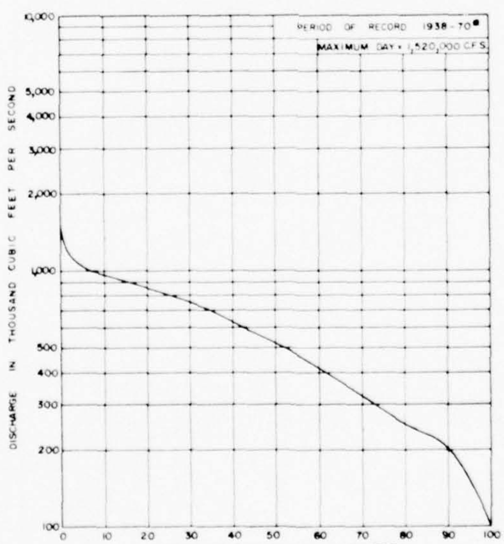


FIGURE 87 DURATION CURVE
0-1120 MISSISSIPPI RIVER AT TARBERT LANDING, MISS.
* RED RIVER LANDING, LA., PRIOR TO JULY, 1963

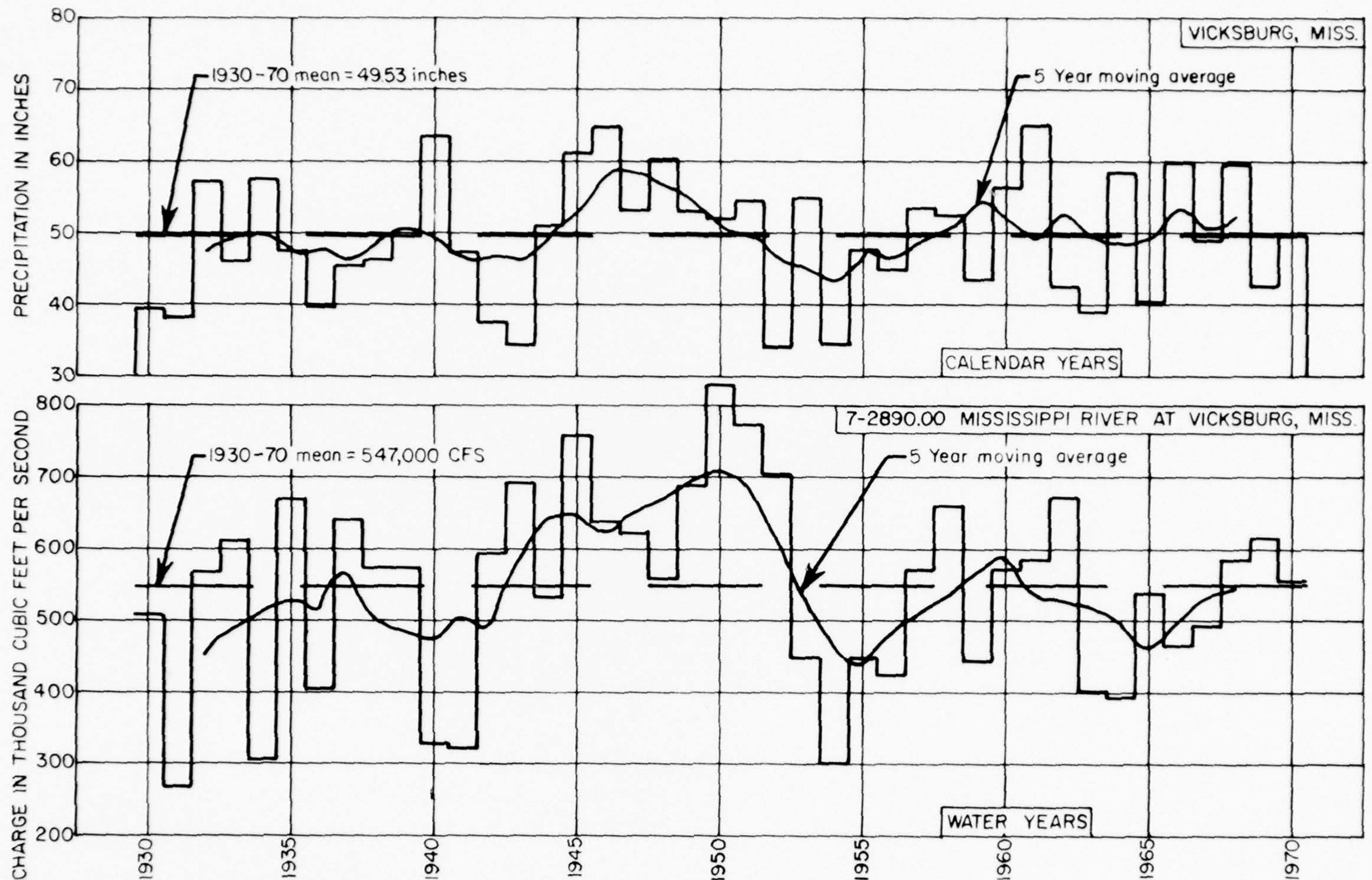
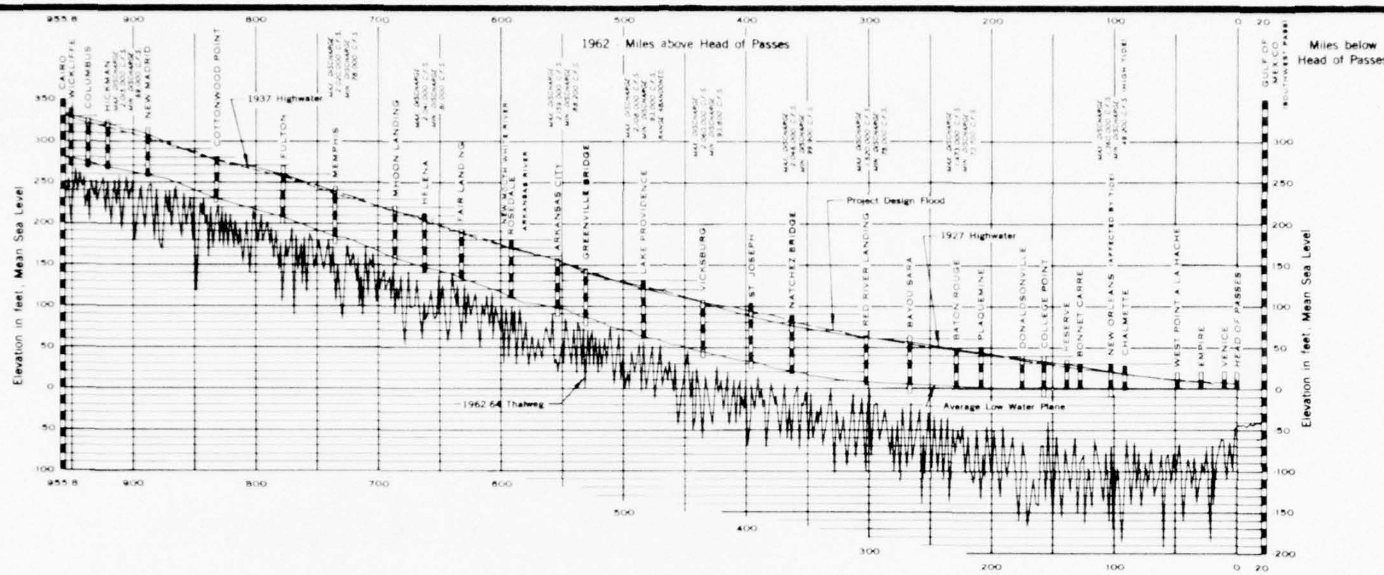


FIGURE 88 LONG-TERM VARIATION IN PRECIPITATION AND STREAMFLOW



GAGE	1962 MILES A.H.P.	GAGE ZERO FT. M.S.L.	GAGE READING FT. HIGHEST	LOWEST	BANKFULL	* ALWP
CAIRO, ILL. (OHIO RIVER)	955.8	270.47	59.51	-1.0	44	8.9
WICKLIFFE, KY. (A)	951.5	269.12	58.18	4.95	42	9.5
COLUMBUS, KY.	937.2	266.38	54.54	0.05	43	7.4
HICKMAN, KY. (B)	922.0	264.73	51.5	-0.4	37	3.1
NEW MADRID, MO.	889.0	255.48	47.97	-0.60	40	2.6
COTTONWOOD POINT, MO.	832.7	230.18	44.4	-3.9	36	-0.5
FULTON, TENN.	778.2	208.61	47.25	-7.7	34	-1.4
MEMPHIS, TENN.	735.9	183.91	48.7	-5.19	35	-1.0
MHOON LANDING, MISS.	687.5	161.22	53.2	-8.85	35	-3.7
HELENA, ARK.	663.3	141.70	60.21	-3.0	41	4.7
FAIR LANDING, ARK. (C)	632.5	132.20	55.6	-4.8	40	0.4
ROSEDALE, MISS.	592.2	108.73	60.2	-4.2	44	0.5
ARKANSAS CITY, ARK.	554.1	96.66	59.2	-5.3	44	0.00
GREENVILLE (BRIDGE), MISS. (D)	531.3	74.92	64.1	4.0	48	10.5
LAKE PROVIDENCE, LA.	487.2	69.71	50.7	-6.8	37	—
VICKSBURG (CANAL), MISS.	437.1	46.25	58.4	-6.8	42	—

* AVERAGE LOW WATER PLANE

GAGE	1962 MILES A.H.P.	GAGE ZERO FT. M.S.L.	GAGE READING FT. HIGHEST	LOWEST	BANKFULL	* ALWP
VICKSBURG, MISS.	437.0	46.23	57.7	-6.8	43	-1.5
ST. JOSEPH, LA.	396.4	33.12	55.3	-8.5	40	-1.0
NATCHEZ, MISS.	363.3	17.28	58.0	-1.6	48	3.0
RED RIVER LANDING, LA.	302.4	3.49	57.45	-0.6	43	3.83
BAYOU SARA, LA.	266.3	3.76	51.7	-2.8	32	0.92
BATON ROUGE, LA.	228.4	-0.52	47.8	0.45	30	3.09
PLAQUEMINE, LA.	208.8	0.04	43.0	-0.94	25	1.66
DONALDSONVILLE, LA.	175.4	-1.19	37.2	0.8	24	2.52
COLLEGE POINT, LA.	157.4	0.42	31.9	-1.02	17	0.64
RESERVE, LA. (B)	138.7	0.00	26.0	-0.1	15	0.70
BONNET CARRE, LA. (C)	128.0	0.08	23.71	-0.7	14	0.60
NEW ORLEANS, LA.	102.8	0.00	21.27	-1.6	11	0.48
CHALMETTE, LA.	91.0	-2.22	19.8	1.7	11	2.30
WEST POINTE A LA HACHE, LA.	48.7	-0.06	15.31	-1.0	7	0.00
EMPIRE, LA. (F)	29.5	0.00	**6.89	-0.60	2	-0.21
VENICE, LA. (G)	10.7	0.00	8.79	-0.64	2	-0.36
HEAD OF PASSES, LA. (E)	-0.5	0.00	6.57	-0.85	1	-0.36

NOTE: RIVER MILES REFER TO LATEST POSITION

(A) GAGE ESTABLISHED IN 1932
(B) GAGE ESTABLISHED IN 1979
(C) GAGE ESTABLISHED IN 1930
(D) GAGE ESTABLISHED IN 1940
(E) FOR PERIOD 1 JULY 1930 TO DATE
(F) FOR PERIOD FEBRUARY 1944 TO DATE
(G) FOR PERIOD JANUARY 1960 TO DATE
** EXCEEDED BY HURRICANE BETSY (1965) RECORD NOT AVAILABLE

FIGURE 89

LOWER MISSISSIPPI RIVER

PROFILE

CAIRO, ILL., TO GULF OF MEXICO

Table 25 - Observed Mean Discharge, Thousands of c.f.s., Sta 7-0242, Miss. River at Hickman, Ky.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1945	206	163	221	521	457	1343	1129	800	848	404	248	223	547
1946	358	325	391	895	737	724	504	554	536	357	279	184	487
1947	200	373	285	672	468	420	910	780	902	644	228	175	505
1948	144	203	221	304	630	951	1133	521	287	388	280	149	434
1949	137	282	571	888	1080	844	705	389	432	408	236	226	516
1950	275	239	438	1249	1426	837	798	723	632	458	353	428	656
1951	259	366	581	688	881	977	1013	690	554	839	360	407	635
1952	268	463	776	807	916	884	960	690	421	313	250	173	577
1953	129	138	218	346	475	678	611	620	404	292	220	144	356
1954	112	112	149	305	252	325	392	432	322	264	190	177	253
1955	295	204	242	429	498	1020	700	404	336	257	176	130	391
1956	199	223	189	127	821	800	643	440	352	296	277	183	379
1957	133	144	299	360	897	442	786	600	549	462	216	180	422
1958	181	483	646	515	420	529	576	789	416	641	634	266	508
1959	197	206	218	381	738	583	569	462	333	229	215	174	359
1960	323	272	489	588	548	484	906	604	499	441	221	223	467
1961	169	210	188	252	338	1109	858	1138	510	314	300	314	475
1962	272	420	530	567	771	1188	1055	448	446	332	212	217	538
1963	226	269	222	257	262	975	560	391	294	215	183	137	333
1964	114	132	140	224	262	882	719	492	298	210	151	156	315
1965	174	176	344	466	559	681	1030	588	400	347	182	383	444
1966	345	226	229	380	600	434	477	744	318	209	205	165	361
1967	183	239	470	280	375	727	589	796	484	476	293	198	426
1968	234	332	668	507	561	471	676	484	603	318	320	168	445
1969	221	290	339	496	855	415	827	631	413	672	302	226	474
1970	316	287	282	421	576	525	796	839	522	246	263	290	447
Mean	218	261	360	497	631	740	766	617	466	386	261	219	452

Table 26 - Observed Mean Discharge, Thousands of c.f.s., Sta 7-0320, Miss. River at Memphis, Tenn.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1945	220	172	228	570	409	1310	1229	837	854	483	276	217	568
1946	376	329	404	960	776	767	571	545	550	391	288	193	512
1947	209	382	312	673	546	409	894	844	934	732	253	205	532
1948	154	219	234	320	607	947	1166	609	286	389	312	160	449
1949	145	291	578	887	1121	904	807	402	442	431	242	224	536
1950	275	250	446	1214	1483	971	857	782	643	480	383	423	679
1951	281	348	636	710	876	1054	1051	761	545	860	409	421	662
1952	295	461	771	852	995	900	1055	735	429	330	258	182	604
1953	132	139	227	340	494	712	622	677	425	314	237	153	372
1954	120	114	146	294	296	332	395	454	336	284	193	191	263
1955	277	218	234	428	464	995	810	436	348	270	188	135	400
1956	198	215	204	127	807	850	683	475	372	316	296	192	393
1957	140	146	289	347	927	470	780	603	616	486	238	180	431
1958	179	486	682	561	462	533	608	826	422	606	685	279	529
1959	220	215	240	361	765	628	580	469	360	238	224	177	370
1960	323	286	497	606	571	510	926	611	498	484	222	222	479
1961	172	211	191	267	305	1079	892	1121	548	318	325	304	479
1962	295	419	560	575	807	1213	1162	496	460	393	226	227	562
1963	233	266	224	286	258	900	668	387	317	214	192	151	342
1964	118	131	154	207	294	830	794	559	312	239	160	161	330
1965	181	173	381	492	587	683	1048	630	432	361	199	365	460
1966	388	250	241	415	551	477	468	796	353	226	211	176	379
1967	186	244	461	306	381	719	606	820	509	520	310	204	439
1968	243	341	642	553	604	456	725	475	638	331	339	177	460
1969	232	295	349	495	933	420	824	696	420	701	351	237	496
1970	327	290	299	456	591	562	768	904	562	298	275	275	467
Mean	228	265	370	512	650	755	807	652	485	411	280	224	470

Table 27 - Observed Mean Discharge, Thousands of c.f.s., Sta 7-0479.7, Miss. River at Helena, Ark.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1945	226	174	233	601	394	1226	1263	865	866	534	295	221	575
1946	404	343	418	946	773	793	591	552	556	407	308	204	525
1947	219	379	314	667	580	414	876	845	911	742	252	207	534
1948	157	219	246	346	549	962	1182	659	278	386	328	167	457
1949	151	280	564	863	1164	978	863	427	466	438	264	234	558
1950	281	266	445	1196	1575	1065	880	816	652	493	393	431	708
1951	290	346	630	712	886	1070	1063	813	539	854	437	431	673
1952	296	452	810	867	996	884	1120	761	461	350	261	189	621
1953	133	141	226	335	499	727	657	709	453	327	242	160	384
1954	121	122	152	291	319	339	401	466	337	285	199	191	269
1955	268	230	234	439	446	978	888	465	365	279	198	141	411
1956	204	215	213	132	792	881	702	492	365	317	298	195	401
1957	142	149	291	350	914	502	774	614	671	506	260	194	447
1958	194	502	726	595	492	532	633	868	432	595	711	285	547
1959	229	213	246	342	794	669	604	489	386	248	236	184	387
1960	329	289	496	616	580	518	931	639	510	506	231	225	489
1961	179	216	208	278	301	1099	454	1198	598	325	342	293	499
1962	298	404	571	590	825	1217	1230	523	458	342	227	229	577
1963	236	254	217	277	257	872	703	390	324	219	197	155	342
1964	121	131	154	204	290	823	845	576	305	254	158	160	335
1965	183	176	376	493	601	675	1058	657	419	357	204	360	463
1966	400	244	236	434	564	506	461	820	370	224	214	176	387
1967	191	242	454	308	378	709	589	814	529	539	320	212	441
1968	238	330	635	573	632	450	755	489	670	332	348	181	468
1969	229	286	362	513	984	431	832	712	432	728	380	251	508
1970	318	281	289	436	592	573	801	945	572	283	263	266	468
Mean	232	265	375	516	661	765	833	677	497	418	291	229	480

Table 28 - Observed Mean Discharge, Thousands of c.f.s., Sta 72654.5, Miss. River at Arkansas City, Ark. 1/

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1929	270	383	619	528	762	1069	1477	1528	1333	668	288	186	759
1930	218	448	457	872	971	881	533	522	363	215	118	144	478
1931	137	128	177	152	228	370	568	456	325	214	206	202	264
1932	179	167	606	947	1320	780	813	552	324	540	268	184	557
1933	181	227	301	749	822	771	1159	1140	920	270	244	228	584
1934	170	153	240	391	189	579	677	310	203	176	171	184	287
1935	189	201	351	480	652	856	1320	1010	1220	882	407	250	652
1936	141	283	360	447	370	711	1116	548	252	185	114	128	388
1937	263	340	251	948	1979	916	512	879	557	402	238	210	625
1938	164	242	223	424	757	895	1125	655	861	559	491	269	555
1939	253	217	236	347	1019	1357	1133	854	450	438	258	144	559
1940	99	112	121	132	266	569	634	696	374	312	219	222	313
1941	120	138	255	358	387	308	506	423	473	356	179	252	313
1942	505	684	341	394	611	773	985	644	592	686	362	346	577
1943	305	378	501	982	654	673	981	1077	1280	606	343	213	666
1944	162	200	169	235	342	959	1209	1318	641	456	249	269	517
1945	265	197	288	661	458	1548	1788	1206	1121	754	327	244	738
1946	562	381	463	1069	934	932	751	706	749	486	321	218	631
1947	221	456	471	726	625	429	965	1061	985	811	278	220	604
1948	169	240	284	409	592	1091	1237	770	343	560	442	197	528
1949	168	293	598	976	1425	1107	968	571	614	519	304	264	651
1950	329	322	464	1319	1747	1237	958	954	735	590	573	555	815
1951	351	364	678	750	980	1201	1111	928	637	1021	531	486	753
1952	333	535	916	983	1083	980	1252	878	493	364	271	207	691
1953	145	149	285	357	543	802	787	863	530	344	262	172	437
1954	133	138	167	312	376	367	420	575	381	306	213	199	299
1955	264	245	236	480	463	983	970	524	442	322	221	156	442
1956	236	221	239	146	839	946	716	524	383	325	304	208	424
1957	153	158	282	362	974	597	936	891	1066	662	341	240	555
1958	232	536	789	653	553	614	781	1032	511	680	804	323	626
1959	254	244	296	347	822	758	647	523	436	300	282	203	426
1960	483	348	529	704	658	591	969	751	589	547	270	259	558
1961	202	248	257	307	313	1116	1124	1283	762	401	399	359	564
1962	369	490	676	710	993	1335	1341	619	495	341	255	259	657
1963	274	286	253	320	293	848	829	420	369	245	223	177	378
1964	141	147	177	219	315	832	972	666	329	280	182	189	371
1965	206	199	433	552	687	767	1131	749	506	415	247	390	524
1966	476	278	259	492	631	618	509	948	442	251	241	206	445
1967	211	263	480	356	408	728	678	958	593	637	374	250	487
1968	278	397	686	716	751	562	951	681	820	388	377	207	567
1969	249	330	488	644	1226	574	955	878	521	780	421	264	607
1970	370	330	353	552	648	696	888	1149	666	344	310	292	549
Mean	248	288	387	560	730	827	938	800	612	468	308	242	534

1/ Published as Mississippi River at Chicot, Arkansas, prior to 1943

Table 29 - Observed Mean Discharge, Thousands of c.f.s., Sta 72890.00, Miss. River at Vicksburg, Miss.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1929	284	363	619	516	812	999	1464	1530	1523	744	340	223	785
1930	241	429	470	838	1046	933	618	553	452	266	143	147	511
1931	144	132	182	160	210	370	553	479	362	230	224	214	272
1932	182	165	619	924	1300	928	827	580	334	560	278	205	573
1933	193	239	329	833	864	818	1140	1160	1050	293	264	246	616
1934	182	165	249	429	204	583	735	341	216	184	172	191	305
1935	202	206	402	496	720	838	1357	1076	1181	942	433	281	677
1936	154	290	368	473	402	695	1093	636	264	198	125	127	402
1937	263	356	267	869	1944	1146	567	896	583	430	251	222	641
1938	175	275	237	452	759	963	1135	691	839	546	493	269	567
1939	267	214	248	349	958	1367	1179	936	469	476	276	160	573
1940	110	122	130	146	263	608	647	751	388	352	235	256	333
1941	134	157	280	388	413	325	495	467	454	369	197	251	327
1942	493	709	361	408	596	805	1044	716	605	711	369	346	596
1943	321	382	523	987	675	672	1040	1072	1383	677	363	228	693
1944	174	213	179	242	333	959	1227	1392	702	483	262	279	537
1945	278	200	294	698	459	1494	1848	1315	1117	831	356	257	764
1946	554	368	485	1021	989	957	792	687	783	531	329	232	642
1947	230	448	471	718	698	461	952	1088	1021	881	296	230	623
1948	174	249	301	418	594	1175	1331	867	356	576	471	207	560
1949	174	301	637	1021	1500	1241	1071	627	632	538	328	270	690
1950	331	348	447	1269	1796	1414	1061	953	780	617	604	580	844
1951	388	366	703	769	996	1241	1143	977	655	1010	580	484	775
1952	347	531	923	1013	1113	966	1262	929	514	375	276	222	705
1953	154	154	294	352	561	838	817	857	578	359	278	188	452
1954	145	142	173	296	406	373	409	583	380	310	216	198	302
1955	258	270	239	491	466	976	1010	567	456	332	230	166	455
1956	238	217	243	150	810	955	735	546	397	334	309	214	427
1957	158	160	286	388	983	644	909	892	1106	736	375	274	572
1958	260	574	866	715	595	627	806	1070	565	682	849	358	663
1959	304	254	313	333	823	791	681	558	476	303	303	216	443
1960	484	354	517	715	702	650	944	794	638	586	282	271	578
1961	215	249	272	315	315	1090	1164	1261	897	430	430	357	584
1962	377	479	681	729	988	1276	1368	729	528	385	296	280	674
1963	299	295	280	351	318	851	901	433	392	269	240	192	402
1964	149	152	185	221	322	821	1033	755	348	327	213	213	395
1965	230	211	472	567	695	774	1166	803	517	428	272	385	542
1966	503	287	268	504	631	675	504	982	489	270	253	225	466
1967	212	268	465	392	416	684	695	853	616	642	378	245	491
1968	275	390	675	764	767	553	1029	701	839	416	407	236	586
1969	268	340	523	632	1233	613	917	898	525	747	438	287	615
1970	361	340	369	588	616	698	877	1158	693	380	326	288	557
Mean	259	294	401	570	745	854	965	837	645	494	328	255	555

Table 30 - Observed Mean Discharge in Thousands of c.f.s., Sta 01100, Miss. River at Tarbert Landing, Miss.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1938	154	248	215	472	679	847	1001	709	702	465	422	226	512
1939	233	171	217	303	718	1060	985	826	410	392	234	144	474
1940	96	97	103	124	219	488	534	665	349	359	238	214	290
1941	114	142	301	376	372	333	428	464	416	355	190	220	309
1942	417	609	333	358	469	659	853	708	575	655	343	325	525
1943	278	324	435	805	538	536	889	836	1146	573	283	187	569
1944	145	168	148	218	296	801	1024	1176	703	421	225	232	463
1945	214	155	234	728	464	1457	1864	1438	1156	893	350	256	767
1946	572	336	443	731	854	817	649	587	673	464	271	189	549
1947	174	357	365	550	539	365	661	810	714	581	204	161	457
1948	129	181	227	340	444	866	897	687	289	458	370	163	421
1949	132	240	478	756	1156	1066	915	558	515	428	273	214	561
1950	259	292	322	948	1372	1185	864	801	670	490	481	460	679
1951	329	267	529	576	789	958	931	782	537	757	476	366	608
1952	270	384	680	790	851	741	961	743	399	279	209	166	539
1953	120	117	239	269	460	670	669	772	570	329	240	153	384
1954	113	105	135	224	331	293	316	524	316	234	170	155	243
1955	188	215	179	387	380	741	866	468	352	270	197	139	365
1956	198	167	199	120	645	794	601	438	298	246	256	162	342
1957	122	122	214	296	777	585	755	796	900	631	302	205	474
1958	211	451	718	611	520	481	598	862	518	519	651	295	536
1959	265	198	255	241	627	636	557	444	391	237	247	175	356
1960	365	276	408	593	581	548	709	579	464	426	227	199	448
1961	165	196	228	289	274	858	967	892	711	351	329	259	460
1962	290	346	590	626	770	941	1050	626	382	269	205	204	525
1963	231	216	211	253	224	534	625	502	276	215	190	153	286
1964	128	135	163	182	255	613	839	804	337	299	170	169	341
1965	195	171	362	441	530	628	836	629	387	309	210	249	412
1966	253	216	217	411	620	673	366	740	392	207	185	171	371
1967	166	201	329	288	281	462	501	626	509	476	287	200	360
1968	215	285	482	617	594	411	792	546	661	301	276	181	447
1969	197	238	394	456	919	533	695	696	395	508	310	215	463
1970	263	260	273	448	430	529	652	852	536	283	239	213	415
Mean	218	239	322	449	575	700	782	709	535	414	280	213	453

Note: Red River Landing, La., discontinued 12 July 1963. Subsequent discharges from Tarbert Landing, Miss.

Table 31 - Observed Mean Discharge in Thousands of c.f.s., Lower Old River near Torras, La.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1938	24	29	11	14	72	129	176	61	151	109	95	46	76
1939	47	32	41	30	135	262	192	160	53	98	50	28	94
1940	17	18	16	16	13	111	95	118	30	17	3	40	41
1941	18	11	-30	-2	26	-7	44	14	16	32	22	35	-21
1942	72	107	37	49	99	141	185	61	43	141	61	57	88
1943	58	66	95	202	133	128	209	219	341	125	74	47	141
1944	34	39	30	20	24	152	239	282	68	89	60	62	92
1945	60	37	34	100	32	293	395	213	227	147	42	49	136
1946	110	56	90	187	163	148	125	92	127	97	72	52	110
1947	45	84	62	114	124	46	169	216	205	206	60	44	114
1948	34	40	34	58	88	224	283	163	58	142	120	44	107
1949	34	54	127	209	360	280	206	115	143	135	82	67	151
1950	65	66	85	298	470	299	228	191	153	142	134	105	186
1951	72	87	177	168	229	298	279	268	145	249	164	124	188
1952	88	116	213	260	275	222	323	205	105	100	72	58	170
1953	37	33	54	67	105	172	171	154	56	45	53	39	82
1954	31	30	32	52	77	80	82	94	61	65	48	46	58
1955	50	51	48	112	80	232	255	118	96	74	49	39	100
1956	45	47	58	32	163	239	181	136	104	87	84	57	103
1957	41	40	62	86	231	151	190	161	230	131	87	67	123
1958	52	70	175	143	120	121	187	228	93	141	250	83	138
1959	58	52	71	66	205	182	153	134	114	76	75	55	103
1960	112	90	112	144	142	127	241	204	166	161	72	67	136
1961	52	53	37	33	39	261	274	317	259	83	98	90	133
1962	104	118	142	133	183	232	379	157	89	78	66	73	146
1963	76	76	66	82	74	140	126	36	31	1/			
Mean	55	58	74	103	141	180	207	158	122	111	80	59	112

Note: -Current during the year was toward the Atchafalaya River except during months indicated by a minus (-) sign, when the current was flowing toward the Mississippi River.
1/ Closure of Lower Old River completed July 12, 1963.

Table 32 - Observed Mean Discharge in Thousands of c.f.s., Sta 02100, Old River Outflow Channel near Knox Landing, La.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1963							147	(a) 73	(a) 84	(a) 54	(a) 49	35	
1964	24	22	30	39	64	178	250	11	15	33	36	35	61
1965	42	34	103	(b) 149	(b) 155	(b) 185	300	232	136	104	63	84	132
1966	126	61	56	101	15	73	126	228	117	62	50	46	85
1967	43	56	103	94	96	169	184	215	169	185	104	58	123
1968	66	96	165	196	200	117	246	156	209	103	104	58	143
1969	62	82	117	159	331	131	243	256	148	220	132	82	164
1970	98	89	100	156	160	174	241	339	220	116	88	72	154
Mean	66	63	96	128	146	147	217	189	137	110	78	59	120

Note: (a) Barge accident resulted in emergency operation of control structure, 1 May-10 Aug. Data in this period were estimated.
(b) Barge accident caused emergency operation of gates 22 Jan-18 Mar. Mean daily flow for this period computed from design rating, records fair.

Table 33 - Dependable Yield at Sta 7-0242, Miss. River at Hickman, Ky.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow 1,000 c.f.s.	Percent of 1945-1970 Mean
1	1954	253	56.0
2	1953-1954	304	67.4
3	1953-1955	333	73.8
4	1953-1956	345	76.3
5	1953-1957	360	79.7
6	1953-1958	385	85.2
7	1953-1959	381	84.3
8	1953-1960	392	86.7
9	1953-1961	401	88.8
10	1954-1963	412	91.3
26	1945-1970	452	100.0

Table 34 - Dependable Yield at Sta 7-0320, Miss. River at Memphis, Tenn.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow 1,000 c.f.s.	Percent of 1945-1970 Mean
1	1954	263	56.1
2	1953-1954	318	67.7
3	1953-1955	345	73.6
4	1953-1956	357	76.1
5	1953-1957	372	79.3
6	1954-1959	398	84.8
7	1953-1959	394	84.0
8	1953-1960	405	86.3
9	1953-1961	413	88.0
10	1954-1963	425	90.6
26	1945-1970	469	100.0

Table 35 - Dependable Yield at Sta 7-0479.7, Miss. River at Helena, Ark.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow 1,000 c.f.s.	Percent of 1945-1970 Mean
1	1945	269	56.1
2	1953-1954	326	68.1
3	1953-1955	355	73.9
4	1953-1956	366	76.3
5	1953-1957	382	79.7
6	1963-1968	406	84.6
7	1953-1959	407	84.7
8	1953-1960	417	86.9
9	1953-1961	426	88.8
10	1954-1963	437	91.1
26	1945-1970	480	100.0

Table 36 - Dependable Yield at Sta 72654.50, Miss. River at Arkansas City, Ark.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow 1,000 c.f.s.	Percent of 1929-1970 Mean
1	1931-1931	264	49.5
2	1940-1941	313	58.6
3	1954-1956	388	72.7
4	1953-1956	400	75.0
5	1953-1957	431	80.8
6	1931-1936	455	85.3
7	1953-1959	458	85.9
8	1934-1941	461	86.5
9	1934-1942	474	88.9
10	1931-1940	478	89.6
42	1929-1970	533	100.0

Table 37 - Dependable Yield at Sta 72890.00, Miss. River at Vicksburg, Miss.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow 1,000 c.f.s.	Percent of 1929-1970 Mean
1	1931-1931	272	49.2
2	1940-1941	330	59.7
3	1954-1956	394	71.4
4	1953-1956	409	74.0
5	1953-1957	441	79.9
6	1936-1941	473	85.7
7	1953-1959	473	85.7
8	1934-1941	478	86.5
9	1934-1942	491	88.9
10	1931-1940	495	89.7
42	1929-1970	552	100.0

Table 38 - Dependable Yield at Sta 0112012, Miss. River at Red River Landing, La.

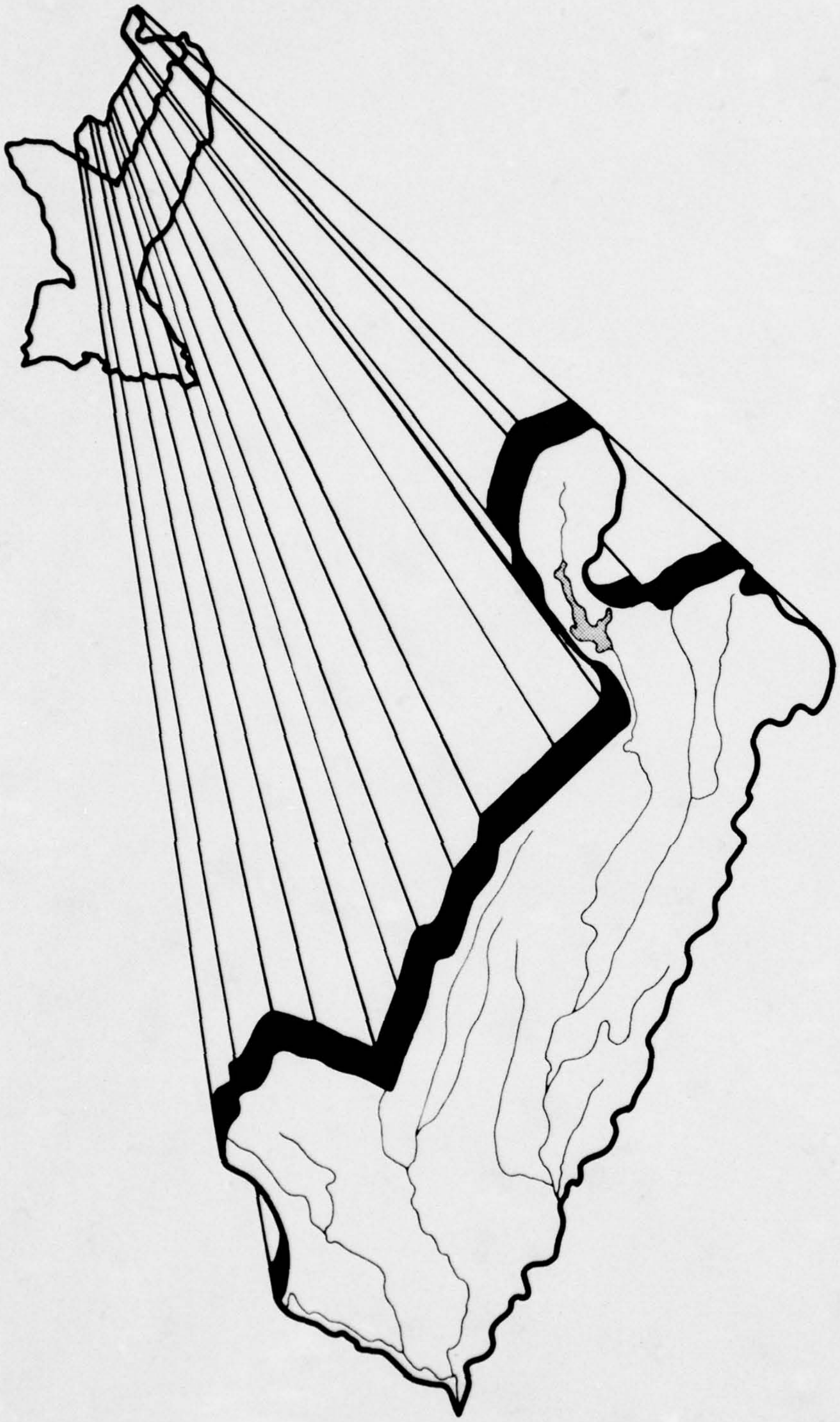
Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow 1,000 c.f.s.	Percent of 1938-1970 Mean
1	1954-1954	243	53.6
2	1940-1941	300	66.2
3	1952-1956	317	70.0
4	1953-1956	333	73.5
5	1963-1967	354	78.1
6	1968-1968	370	81.7
7	1963-1969	383	84.5
8	1953-1960	394	87.0
9	1959-1967	395	87.2
10	1959-1968	401	88.5
33	1938-1970	453	100.0

Table 39 - Chemical Analyses of Water in WRPA 1 from the Mississippi River in the Lower Mississippi Region, Milligrams Per Liter

Geologic units in drainage basin above sampling station	Date sampled	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
							07373420 Mississippi River near St. Francisville, La.												
	10-13-70	--	5.1	0.01	34	9.7	12	4.3	115	36	14	0.2	3.8	184	120	31	312	7.0	5
	11-10-70	--	5.5	--	46	14	24	4.3	143	65	26	.2	4.6	262	170	55	444	7.2	10
	12- 3-70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	411	--	--
	12-17-70	--	8.1	--	51	12	20	3.9	157	61	17	.2	4.4	284	180	49	437	7.6	20
	1- 6-71	--	6.4	.05	39	8.4	13	3.4	106	46	17	.1							
	1-21-71	--	7.0	.03	36	7.8	13	3.0	99	42	16	.1	4.3	189	120	41	304	7.4	10
	2- 4-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	342	--	--
	2-23-71	--	6.8	--	32	7.3	12	2.9	89	39	15	.2	3.2	213	110	37	288	7.2	80
	3- 5-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	315	--	--
	3-18-71	--	14	.02	32	8.0	10	3.1	89	38	13	.2	5.0	172	110	40	287	7.4	20
	4- 6-71	--	9.1	.02	41	12	14	3.7	128	15	15	.2	6.7	230	150	45	365	8.0	5
	4-27-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	403	--	--
	5- 6-71	--	6.6	.02	44	14	18	3.8	152	53	16	.2	3.5	252	170	43	410	8.0	10
	6- 1-71	--	6.7	.03	36	9.7	15	3.4	102	51	15	.2	3.5	199	130	46	332	8.1	15
Quaternary Terrace and Alluvial Deposits	6-15-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	398	--	--
	9-15-71	--	4.5	.02	42	13	27	3.5	150	57	24	.2	1.0	264	160	34	438	7.0	20
							07373423 Mississippi River below St. Francisville, La.												
	10-13-70	--	5.0	0.01	36	8.8	13	4.1	118	38	17	0.2	2.0	186	130	29	316	6.9	5
	10-27-70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	374	--	--
	11-10-70	--	4.5	--	44	13	21	4.3	142	58	21	.2	4.1	254	160	46	427	7.2	5
	12- 3-70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	421	--	--
	12-16-70	--	5.5	--	50	14	18	3.6	155	61	18	.2	4.5	257	180	57	433	7.2	5
	1- 6-71	--	7.0	.04	38	8.5	13	3.2	103	46	16	.1	4.0	189	130	45	323	7.2	25
	2- 4-71	--	7.8	.04	40	11	12	2.0	120	45	16	.2	2.9	196	140	46	332	7.0	15
	2-18-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	347	--	--
	3- 5-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	308	--	--
	3-25-71	--	7.5	.02	33	9.1	11	3.4	101	39	14	.2	4.7	184	120	37	303	8.0	5
	4- 6-71	--	8.6	.02	40	12	13	3.4	128	46	15	.2	4.5	218	150	44	361	7.9	10
	5- 6-71	--	7.1	.03	44	14	18	3.7	148	56	17	.3	3.5	243	170	46	410	8.0	15
	6- 2-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	344	--	--
	6-15-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	410		
	6-12-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	449	--	--
	9-15-71	--	3.9	.02	42	12	26	3.4	142	57	24	.2	1.5	260	160	40	437	7.3	15

Table 39 - Chemical Analyses of Water in WRPA 1 from the Mississippi River in the Lower Mississippi Region, Milligrams Per Liter (Con.)

Geologic units in drainage basin above sampling station	Date sampled	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
							07374400 Mississippi River at Luling Ferry, La.												
	10-13-70	--	7.2	0.02	35	8.4	17	3.7	112	38	18	0.3	2.5	195	120	30	327	7.2	10
	11-25-70	--	7.5	.02	47	12	25	2.3	131	64	28	.4	5.7	270	170	59	449	7.8	10
	12-21-70	--	8.4	.04	52	14	24	3.4	157	69	26	.4	6.0	295	190	66	482	7.5	15
	2-19-71	--	7.7	.01	40	12	18	3.0	128	50	21	.4	2.6	229	150	50	381	7.9	10
	3-24-71	--	7.5	.01	37	5.6	13	3.3	104	44	16	.3	4.8	200	130	43	319	7.9	10
	5- 3-71	--	7.8	--	48	15	21	3.0	142	62	23	.5	4.1	299	180	61	441	7.6	10
	6- 4-71	--	6.1	--	40	8.5	20	2.7	105	57	21	.4	3.1	244	140	49	370	7.5	10
	7-21-71	--	5.8	--	54	14	33	3.3	159	73	34	.8	2.0	232	190	61	524	7.3	10
	8-26-71	--	4.7	--	46	11	28	3.0	125	68	29	.5	3.3	281	160	56	449	7.8	10
							07374508 Mississippi River at New Orleans, La.												
Quaternary Terrace and Alluvial Deposits	10-20-70	--	6.5	0.02	40	9.7	21	3.6	121	47	24	0.5	2.6	226	140	41	385	7.0	10
	11-12-70	--	6.2	.03	46	13	25	3.6	134	66	26	.5	3.7	274	170	58	451	7.0	10
	12- 8-70	--	7.8	.02	46	13	22	3.2	132	69	24	.4	5.3	261	170	62	444	7.5	10
	1- 7-71	--	6.6	.04	41	8.4	16	3.5	104	48	21	.3	5.1	211	140	52	349	7.6	30
	2- 2-71	--	8.1	.07	40	8.8	14	1.9	105	48	19	.3	4.6	202	140	50	337	7.1	15
	2-25-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	306	--	--
	3-16-71	--	7.4	.03	35	7.4	12	3.4	94	38	15	.3	5.8	193	120	41	299	7.9	10
	3-30-71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	344	--	--
	4-27-71	--	8.7	.02	52	13	21	3.2	152	62	23	.6	4.9	272	180	60	453	8.0	10
	5-26-71	--	6.2	.06	40	10	18	3.0	112	57	20	.4	3.6	218	140	50	373	8.0	20
	6- 9-71	--	6.7	.01	43	9.9	21	3.1	126	61	21	.4	.2	241	150	45	399	7.4	15
	7- 2-71	--	7.0	.01	46	11	28	3.4	138	59	30	.4	2.7	277	160	49	459	7.3	15
	8-18-71	--	7.1	.02	42	11	27	3.4	132	59	27	.4	2.0	256	150	42	432	7.3	20
	9-13-71	--	2.3	.02	46	12	29	3.4	136	66	29	.6	1.8	276	160	52	464	7.5	20



WRPA 2

W R P A 2

INTRODUCTION

WRPA 2 consists of that part of Missouri containing the St. Francis River Basin and the St. Johns Bayou-New Madrid Floodway area; and the part of Arkansas containing the St. Francis River Basin, the White River Basin below Georgetown, and the left bank of the Arkansas River Basin below Pine Bluff. The area covers 16,723 square miles, or about 16 percent of the total area of the Lower Mississippi Region.

The area is bounded on the north by the St. Francis Basin Divide, on the west by the Southwestern Division-Lower Mississippi Valley Division boundary, on the south by the Arkansas River, and on the east by the Mississippi River. The area is about 300 miles in length with a maximum width of about 80 miles. The highest elevations in the area are found in the Ozark Highlands in the north with the highest elevation being about 1,770 feet above mean sea level (m.s.l.). The lowest elevations are found along the lower end of the White River at about 140 feet m.s.l.

About 90 percent of WRPA 2 is nearly flat alluvial valley delta land with the main physiographic feature being Crowleys Ridge which extends lengthwise through and mainly in the middle of the St. Francis Basin. The eastern slopes of the ridge are rather steep, and they grade into the alluvial plains of the river valleys.

The Sikeston Ridge and Malden-Kennett Prairie are low terraces on the alluvial plain; they lie east of Crowleys Ridge and rise 10 to 20 feet above the lowland plains. West of Crowleys Ridge, there are other small isolated terraces. The long, narrow, low drainage basins of the streams and drainage ditches are alined parallel to these low terraces.

Streams originating within this WRPA averaged about 16 inches of runoff per year, or 19,770 c.f.s., during the period of record.

Of the three major river systems in WRPA 2, the stream gradients for the St. Francis are the highest, ranging from about 3.0 feet per mile in the upper reaches to about 0.5 foot per mile in the lower reaches. The St. Francis Basin contributes about 15 inches of runoff per year in WRPA 2.

The stream gradient for the Lower White is about 0.4 foot per mile. The runoff originating in the White River Basin within WRPA 2 averages about 19 inches per year. The portion of the White Basin which is outside WRPA 2 averages about 16 inches of runoff per year.

The stream gradient for the Lower Arkansas River is about 0.6 foot per mile. The runoff originating in the Arkansas River Basin within WRPA 2 averages about 14 inches per year, and the portion of the basin which is outside WRPA 2 averages only about 3 inches per year.

The streams in this area flow through an alluvial valley consisting of 10 to 50 feet of silts and clays underlain by sands and gravels 30 to 150 feet thick.

The largest cities in the area, with their 1970 populations, are: Blytheville, Ark. - 24,752; West Memphis, Ark. - 26,070; Jonesboro, Ark. - 27,050; and Pine Bluff, Ark. - 57,389.

SURFACE WATER

The majority of the streamflow which originates within WRPA 2 is produced by the St. Francis and White River Basins. There is some slight regulation on the St. Francis River as a result of Wappapello Dam. This structure regulates a drainage area of 1,310 square miles. The flow which originates within WRPA 2 on the White River has no regulation. The flow entering from outside WRPA 2 on the White River is partly regulated by upstream dams.

Quantity

The annual mean discharge of streams originating in WRPA 2 is 19,770 c.f.s. (14.3 million acre-feet annually). This averages 1.2 c.f.s. per square mile. This is an intermediate rate when compared with that for the rest of the region. An additional 65,500 c.f.s. flows into the area from outside.

Present Utilization

Withdrawals from surface water sources in WRPA 2 during 1970 averaged about 1,850 c.f.s., which was equivalent to less than 10 percent of the mean annual flow generated within the area. Surface water withdrawals constituted less than 34 percent of the total water withdrawn in the area, with the remainder coming from ground water sources. Major surface water withdrawals were for fish and wildlife enhancement (810 c.f.s.), thermoelectric power production (610 c.f.s.), and irrigation (410 c.f.s.).

Ground water withdrawals from WRPA 2 during 1970 were greater than those from any other WRPA in the region, averaging about 3,700 c.f.s. The major use of ground water withdrawals was for the irrigation of crops (3,440 c.f.s.). Fish and wildlife enhancement (90 c.f.s.) and municipal (50 c.f.s.) and industrial uses (52 c.f.s.) were other sources for ground water withdrawals.

About 3,085 c.f.s., or 55 percent of the total ground and surface water withdrawals from WRPA 2 during 1970, were consumed. The remaining withdrawals of 2,465 c.f.s. were released and returned to nearby streams, thus resulting in a net increase to the area's streamflow of 615 c.f.s. (due to large quantity of ground water withdrawn and released). Major consumptions of water were for irrigation (2800 c.f.s.) and for fish and wildlife enhancement (180 c.f.s.). Recreation was popular in the area and most lakes and streams were used for nonconsumptive purposes such as fishing, boating, and water sports.

Additional information on the withdrawals of ground and surface water in WRPA 2 during 1970 is given in table 15 of the Regional Summary.

This table also presents pertinent data on the consumption of water for various purposes in this area and each of the other WRPA's in the Lower Mississippi Region.

Stream Management

Competition for water among the various users necessitates efficient stream management. In WRPA 2, stream management practices include changes in stream systems by the use of dams for decreasing flood flows and supplementing low flows, the development of levees, channel improvements, and diversion of water for various uses. Some of these practices may not cause marked changes in streamflow and many subsequent years of streamflow records may be required to define their effects on the stream system.

Impoundments

Table 40 gives pertinent data on reservoirs in WRPA 2 which have a total capacity of 5,000 acre-feet or more. Lake Wappapello is the main flood-control reservoir.

Table 40 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, WRPA 5

Name	Stream	Total Storage (acre-feet)	Surface Area (acres)	Purpose 1/
Wappapello Lake	St. Francis River	1,336,200 2/	35,100	F,R
Cox's Lake	Big Slough Ditch	7,200	160	In
Claypool Lake	L'Anguille River	5,200	1,300	R,F
Peckerwood Lake	Lagrue Bayou	20,000	4,000	Ir,R
Bear Creek Lake	Bear Creek	8,000	800	R
John Hampton Lake	Raney Bayou	6,408	1,068	Ir,R

1/ F - Flood Control, R - Recreation, Ir - Irrigation, and In - Industrial.
2/ Includes surcharge and freeboard storage.

The operation of Lake Wappapello for flood-control purposes usually follows a pattern of discharging excess water in mid-December to allow for the storage of runoff from heavy winter and spring rains. Recreation is very popular on the lake; hence, this use of the lake requires that the water be held in the reservoir during the summer months for as long as possible.

Channel modification. Throughout WRPA 2, channel modification has taken place on many of the streams. Extensive flood-protection projects have been built in both the St. Francis Basin and the White River Basin. These projects include, in the St. Francis Basin, Wappapello Dam, levees,

drainage structures, and channel clearing and construction. Projects in the White River Basin include levees, drainage structures, and channel clearing and construction.

Navigation projects have been built on the White and Arkansas Rivers. On the White River, this consists of channel clearing and dredging, while on the Arkansas River it consists of channel improvements and locks and dams. Both the White and the Arkansas Rivers are navigable throughout WRPA 2.

Streamflow

The base period selected for this study varies, depending upon the period of record available at each gage site. At the stations where necessary, the period of record was modified to reflect changes in the streamflow characteristics at the site due to changes in stream management, diversions, channel improvements, or regulations upstream from the site. For each of the selected gaging stations, the selected period of record provides reasonably good data for statistical analysis and study in this report, and the data are considered representative of flows which could occur under 1973 levels of development.

Measurement facilities. Streamflow data at 12 sites in WRPA 2 are considered to be representative of the various drainage and hydrologic conditions which exist in the area. Locations of these sites, identified by U. S. Geological Survey Station numbers, are shown in figure 90, which also shows the mean annual runoff for the area. Table 41 is a summary of streamflow and other pertinent data at each of the selected sites.

Table 41 - Streamflow Summary for Selected Sites, WRPA 2

Stream	Station	Station No.	Gage Datum	Drainage Area (square miles)	Period of Record	Mean Annual Flow 1/ (c.f.s.)			Momentary 2/ Flow (c.f.s.)	
						Mean	Maximum	Minimum	Maximum	Minimum
St. Francis River	Patterson, Mo.	0375	370.45	956	20-69	1,084	2,250	343	100,000	8
St. Francis River	Wappapello, Mo.	0395	324.44	1,311	20-69	1,541 3/	3,089 3/	584 3/	85,000 4/	0
St. Francis River	St. Francis, Ark.	0401	270.57	1,772	30-69	2,111 3/	4,672 3/	550 3/	39,200 4/	55
St. Francis River	Lake City, Ark.	0404.5	217.69	2,374	31-69	3,065 3/	6,766 3/	789 3/	36,700 4/	60
Right Hand Chute of Little River	Rivervale, Ark.	0466	213.15	2,105	47-69	2,811	6,474	844	31,400	80
Tyronza River	Tyronza, Ark.	0476	183.87	290	49-69	421	841	168	5,660	13
St. Francis River	Latitude of Wittsburg, Ark.	0479.02	--	6,475	35-69	7,844 3/	16,947 3/	2,533 3/	74,100 4/	250
L'Anguille River	Palestine, Ark.	0479.5	166.68	786	49-69	1,186	2,618	452	15,600 5/	0
Cache River	Patterson, Ark.	0775	182.96	1,041	37-69	1,391	3,014	403	13,200	0
Bayou De View	Morton, Ark.	0777	187.71	422	39-69	541	1,322	141	6,700	0
White River	Clarendon, Ark.	0778	139.91	25,497	28-69	30,040	62,100	13,100	440,000	2,900
Arkansas River	Little Rock, Ark.	2635	223.61	158,201	28-69	39,820	84,780	10,820	536,000	850

1/ Regulated values for period of record.
2/ Observed values for period of record.
3/ After construction of Wappapello Dam.
4/ Before construction of Wappapello Dam.
5/ Discharge not determined for record high gage.

LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN ANNUAL RUNOFF IN INCHES

WRPA 2

FIGURE 90

Average discharge for WRPA 2. A graphical representation of the average monthly discharge generated within WRPA 2 and contributed to the area from outside the region is shown in figure 91. This figure presents the maximum, mean, and minimum monthly flows at the mouths of the Arkansas, White, and St. Francis Rivers, and includes inflow from outside the area.

Average discharge at selected stations. Tables 42-53 present observed mean flows at each of the selected sites in WRPA 2. The flows are representative of 1973 levels of development in the area. Figures 92-103 present peak flow frequency curves for selected sites in WRPA 2. These curves are a reflection of the annual peak discharges for the station and were computed using the standard method of the Corps of Engineers [6].

Low flow frequency curves for selected sites are shown in figures 104-113. These curves represent the lowest average flows for periods of 3, 7, 14, 30, and 120 consecutive days. Due to regulation of low flows, no curves were computed at the station immediately below Wappapello Dam or at Little Rock, Ark.

Duration curves for daily flows at selected sites in WRPA 2 are presented in figures 114-125. These curves indicate the percent of time that any given flow at the site is equaled or exceeded.

Tables 54-65 present data on the dependable yield characteristics at each of the selected discharge sites. These tables show the lowest mean flows for from one to ten consecutive years out of the period of record. The relationship of these lowest mean flows to the period of record mean is also shown. The minimum yearly flow for the stations in WRPA 2 ranges between 26 and 44 percent and averages 32 percent of the mean annual flow. For the ten consecutive years of lowest mean flow, the dependable yield averages about 82 percent of the mean annual flows for the WRPA.

Flow Velocities

No flow velocities for streams in WRPA 2 were available for publication in this report due to the lack of time of travel studies in the area.

River Profiles

Representative river profiles are presented in figures 126-128. The profiles were prepared using topographic maps and data from available reports.

Quality

Surface water in WRPA 2 is generally suitable for most uses even

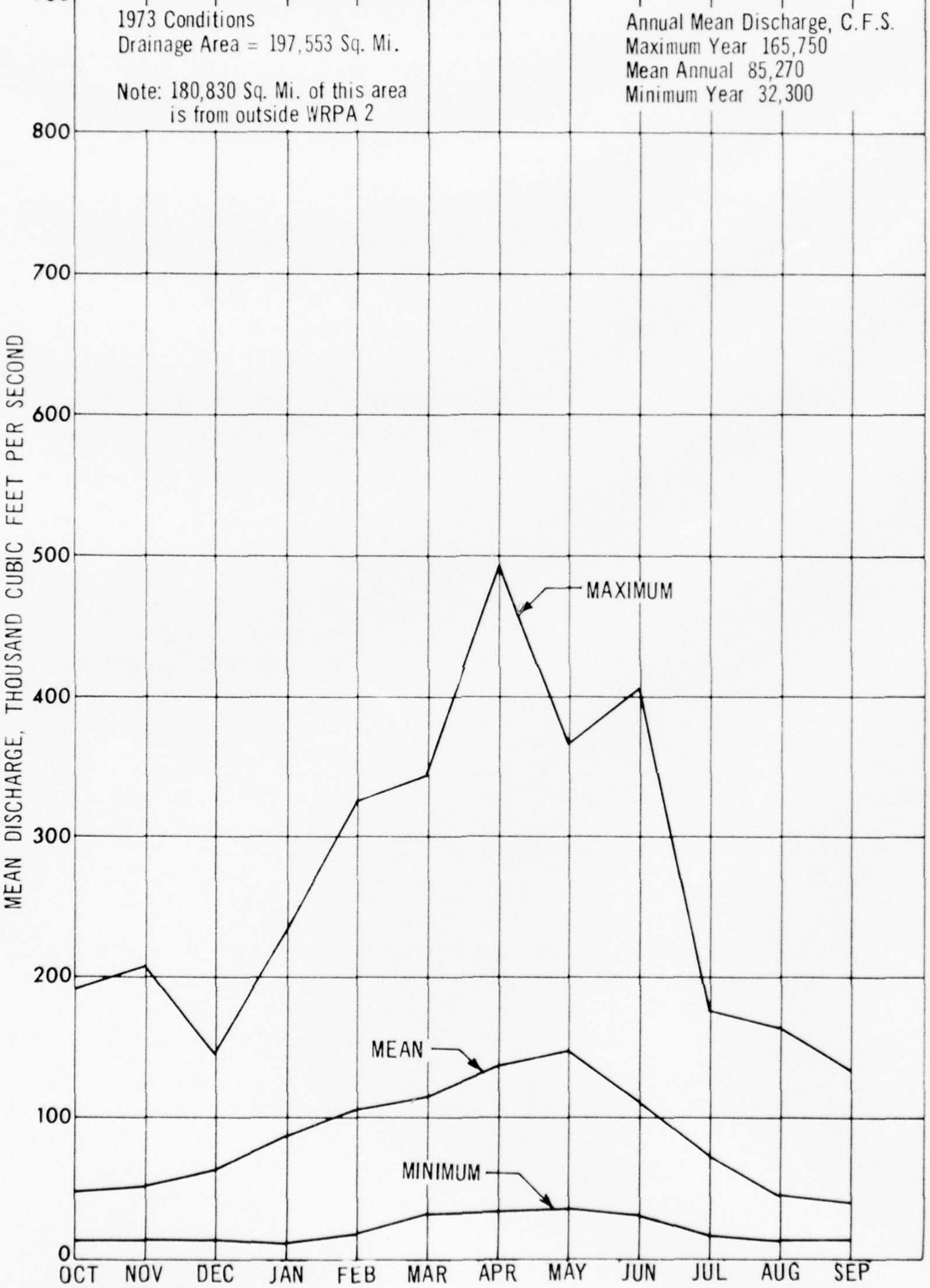


FIGURE 91

MONTHLY DISCHARGE FROM WRPA 2

though it is moderately mineralized (dissolved solids ranged from 90 to 333 mg/l) and hard (hardness greater than 120 mg/l of $CaCO_3$, table 66). The water is suitable for some uses with little or no treatment. However, for municipal and most industrial uses, most of the water requires softening, coagulation, filtration, and pH adjustment [107].

Calcium, magnesium, and carbonate are the principal constituents in waters from streams draining all formations except the Pliocene deposits (table 66). All the streams except ditch 24 at Heagy, Mo., and Big Creek near Jonesboro, Ark., drain terrace or alluvial deposits of Quaternary age.

Ditch 24 at Heagy, Mo., drains Paleozoic rocks and Cretaceous deposits. The chemical characteristics of water in this stream are similar to those of water in streams draining Quaternary deposits. This similarity is to be expected because generally the principal soluble constituents in the Paleozoic rocks and in the outcrop of the Cretaceous deposits are the carbonate salts of calcium and magnesium.

The dissolved-solids content of water in streams draining Quaternary deposits or draining Paleozoic rocks and Cretaceous deposits range from 90 to 333 mg/l. In each stream, however, the quality is fairly uniform during periods of low flow. The areal variation in dissolved solids is caused largely by differences in the composition of the deposits.

The dissolved-solids values of water from Village Creek at Newport, Ark., are much smaller than values for Village Creek at Walnut Ridge, Ark., and for other streams draining the alluvium or terrace deposits. Big Creek near Jonesboro, Ark., drains Pliocene deposits. Bicarbonate is the principal anion in water from these deposits and calcium, magnesium, and sodium are present in about equal quantities. The dissolved-solids content of water from Big Creek near Jonesboro generally is less than that in streams draining other geologic units, probably because the Pliocene deposits do not have as much soluble material as the other deposits.

Table 42 - Observed Mean Discharges in c.f.s., St. Francis River at Patterson, Mo., Sta 7-0375

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1921	25	45	340	840	1,050	3,000	4,600	2,300	210	125	97	274	1,070
1922	266	2,860	1,470	504	1,030	3,800	3,960	710	136	173	120	53	1,250
1923	55	263	723	1,520	3,560	3,620	1,590	3,780	1,160	117	264	226	1,400
1924	204	246	2,210	465	1,420	1,130	644	1,050	1,620	727	632	376	892
1925	132	129	432	405	1,450	770	931	483	393	77	68	485	471
1926	2,910	3,240	1,390	715	2,190	996	1.070	188	107	58	220	231	1,100
1927	823	1,580	699	3,250	1,150	2,850	9,220	4,200	2,610	177	333	109	2,250
1928	171	966	3,070	996	1,260	1,110	3,890	777	8,720	593	545	121	1,840
1929	189	603	1,730	2,290	1,190	1,680	3,200	4,720	1,480	562	192	131	1,500
1930	124	248	882	4,020	1,960	919	353	139	51	30	25	64	730
1931	117	122	206	118	684	1,310	1,010	727	193	75	82	89	393
1932	37	385	1,070	2,620	566	588	436	197	70	62	268	72	534
1933	155	477	2,160	2,270	700	1,100	3,740	5,620	156	146	86	393	1,430
1934	382	130	306	637	145	1,270	1,328	354	85	36	119	694	459
1935	403	1,060	1,151	2,127	723	5,333	1,272	3,819	5,309	797	215	80	1,866
1936	137	1,197	559	239	415	514	903	182	34	21	11	135	360
1937	1,550	1,580	1,002	6,430	2,266	631	2,304	2,118	448	461	57	59	1,575
1938	266	174	1,233	1,353	3,889	3,410	2,113	1,441	498	268	87	37	1,215
1939	37	99	138	1,199	2,282	3,619	3,895	411	379	597	264	58	1,071
1940	80	118	124	383	281	1,574	3,062	901	133	96	109	33	573
1941	32	138	535	1,422	447	178	836	273	94	38	52	78	343
1942	1,624	2,042	818	1,223	2,686	2,008	1,728	977	1,939	248	267	69	1,290
1943	185	1,476	2,424	585	347	1,321	1,479	7,145	1,269	141	178	99	1,399
1944	88	124	121	151	562	1,580	2,430	1,035	156	35	21	36	526
1945	36	54	89	104	2,750	6,981	7,167	1,140	7,210	340	98	687	2,200
1946	1,951	824	420	1,673	3,077	1,451	888	6,162	852	120	282	80	1,478
1947	65	1,043	1,036	806	548	623	4,248	1,330	1,251	703	61	59	977
1948	97	574	440	2,542	1,397	2,244	1,689	1,228	320	735	89	52	951
1949	60	381	558	5,683	2,436	3,413	971	697	1,137	607	97	278	1,358
1950	2,635	318	1,289	6,725	3,845	1,420	2,796	3,346	732	114	635	1,030	2,068
1951	155	337	445	2,038	4,577	1,975	1,448	865	884	2,465	804	1,405	1,429
1952	1,170	4,441	1,452	1,049	1,425	3,339	2,953	381	108	115	94	52	1,376
1953	49	258	483	712	677	2,437	1,162	977	108	63	19	15	581
1954	29	48	61	238	662	283	622	1,405	1,868	67	30	53	443
1955	92	103	1,140	483	1,298	3,002	1,097	754	224	185	40	15	702
1956	68	219	91	65	2,418	694	587	1,594	469	110	39	33	524
1957	34	119	417	673	1,886	1,644	7,264	5,869	2,352	2,513	285	59	1,921
1958	97	1,799	2,718	1,196	940	4,091	2,735	2,114	1,611	2,138	804	211	1,712
1959	124	1,579	483	1,663	1,704	2,199	1,783	832	350	146	103	186	922
1960	776	308	2,643	1,145	1,090	1,688	1,008	2,073	268	76	58	60	938
1961	86	556	1,047	194	1,223	3,444	2,315	3,650	853	152	97	32	1,140
1962	35	86	440	2,775	1,828	3,058	1,290	833	147	59	47	182	896
1963	174	100	290	346	125	1,948	950	2,235	308	128	284	54	585
1964	30	158	115	129	396	4,002	2,433	305	86	48	36	54	650
1965	43	80	149	220	738	652	2,000	256	540	55	19	2,103	563
1966	169	78	397	1,664	2,948	805	5,039	3,584	196	48	130	233	1,259
1967	193	245	1,469	769	1,240	1,161	852	893	144	68	55	75	595
1968	140	154	3,373	963	1,765	2,676	3,796	1,283	269	37	76	59	1,214
1969	45	493	1,810	4,126	1,545	1,853	3,249	703	284	198	37	320	1,221
1970	98	102	193	413	739	2,995	3,105	1,658	1,055	99	615	560	969
Mean	369	675	957	1,483	1,511	2,088	2,389	1,794	1,018	341	185	239	1,084

Table 43 - Observed Mean Discharge, in c.f.s., St. Francis River at Wappapello, Mo., Sta 7-0395

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1942	1000	2930	1030	1120	3770	2960	2780	1070	2390	580	440	220	1692
1943	120	1870	2520	2200	600	1690	2000	3560	4900	1020	340	300	1761
1944	220	240	220	250	370	2200	1060	3040	1550	170	140	200	805
1945	170	130	200	201	818	3040	11900	8220	3490	4870	3380	653	3089
1946	2500	1270	622	2370	4400	2190	1120	8480	2310	418	513	261	2205
1947	46	1180	1830	1030	1060	707	4510	2850	1370	1600	239	196	1385
1948	34	775	907	3820	1540	2670	3470	1410	657	1300	237	201	1418
1949	33	426	1110	5450	7800	4690	2340	804	1680	1020	300	489	2179
1950	3240	466	1890	8870	6340	1980	4160	5190	1210	441	853	1220	2988
1951	65	527	827	2590	5170	3420	1920	1110	1160	3020	858	1720	1866
1952	1100	4960	2860	1720	1930	4400	4020	834	302	180	179	181	1889
1953	41	318	874	813	954	3190	1710	1330	272	211	125	107	829
1954	36	44	296	344	843	648	825	1410	2310	91	64	91	584
1955	91	216	1360	1450	1240	3870	1840	1190	600	408	55	34	1030
1956	34	305	405	191	2500	1420	693	1600	737	181	83	67	685
1957	40	149	762	804	2050	2450	8760	6890	5860	3510	676	108	2672
1958	62	2790	3360	1900	1130	4740	3960	4160	2060	2690	1220	378	2372
1959	106	2470	970	1640	2230	2520	2070	991	865	250	178	396	1225
1960	809	521	2010	1940	1480	1600	1640	2650	659	159	122	118	1218
1961	51	705	1480	463	1140	4210	3460	5530	1660	320	207	95	1610
1962	40	169	929	2899	2259	4317	2275	966	491	109	134	434	1253
1963	242	195	560	617	286	2205	1320	2068	932	233	390	103	763
1964	54	328	570	278	632	5900	3240	489	162	123	115	168	1005
1965	83	243	702	521	1230	1040	2850	289	681	152	40	2160	833
1966	582	207	783	2680	3470	1250	3420	4510	1970	224	380	445	1661
1967	362	411	2100	873	1730	1560	804	1090	311	154	130	888	868
1968	50	48	4500	1410	2780	2860	5450	2370	437	149	291	135	1707
1969	111	490	1830	3220	5160	1850	4250	894	329	264	91	292	1565
Mean	405	871	1372	1845	2318	2700	3137	2679	1477	852	421	416	1541

Note: Regulated Conditions

Table 44 - Observed Mean Discharge, in c.f.s., St. Francis River, St. Francis, Ark., Sta 7-0401

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1941	95	235	910	2090	1090	385	475	520	255	200	170	170	550
1942	840	2920	1757	2270	5080	4170	4430	1140	2740	830	925	351	2288
1943	160	1670	2760	3460	727	2380	2460	4780	5320	1820	463	390	2199
1944	250	276	273	307	612	3180	3410	3820	2140	218	208	212	1242
1945	188	153	256	307	1430	6410	14700	11700	8030	6470	4510	1240	4616
1946	3680	2620	1120	4000	5610	3730	1450	9350	5190	711	666	331	3205
1947	167	1298	2740	1480	1320	835	4290	4580	1370	2360	317	296	1754
1948	165	854	1240	5010	2300	3720	5300	1730	596	1560	361	278	1926
1949	133	595	1860	7020	1230	6570	4590	813	2400	1130	430	588	2280
1950	3750	1160	2760	13700	11700	4350	6380	7300	1940	616	953	1450	4672
1951	342	911	1080	4050	6030	6330	2620	1300	1320	4150	1080	1930	2619
1952	974	5380	6150	3540	3440	6570	6270	1480	525	255	265	231	2923
1953	95	149	1030	933	1120	4560	2290	2090	453	349	212	173	1121
1954	135	78	254	517	1160	1080	1090	1960	2740	275	187	147	802
1955	168	216	1340	2080	1030	4100	3830	1720	979	570	166	96	1358
1956	120	290	455	306	3200	2430	1130	2010	821	380	146	163	954
1957	92	161	735	1370	2980	2940	10230	10060	9290	4620	1330	263	3673
1958	176	5010	4180	3820	1950	5970	6500	6900	2380	2830	2050	518	3524
1959	211	2090	1520	1910	3630	3260	2130	1420	1330	458	318	410	1557
1960	953	635	2770	2800	1920	2160	2370	3620	1040	324	255	159	1583
1961	127	701	1890	681	1310	6130	5330	8760	2500	591	306	187	2376
1962	112	453	1270	3490	4150	6170	4790	1650	589	303	263	646	1991
1963	412	253	539	706	344	3003	1690	1613	1920	342	435	304	963
1964	104	344	574	360	700	8100	5450	1030	338	193	218	381	1483
1965	215	229	1120	1020	2480	1700	3990	673	979	323	121	1810	1222
1966	1560	283	739	4550	4360	1990	3410	7790	2870	270	396	340	2380
1967	583	385	2490	1230	2400	2000	926	2730	445	275	222	899	1215
1968	191	139	4450	3200	3770	3500	7370	4400	820	301	472	226	2403
1969	163	494	2620	5490	8560	2320	5900	1320	482	364	189	314	2351
Mean	558	1034	1755	2817	2953	3795	4303	3733	2131	1141	609	501	2111

Note: Regulated Conditons

Table 45 - Observed Mean Discharge, in c.f.s., St. Francis River, Lake City, Ark., Sta 7-0404.5

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1941	140	260	1160	2500	2140	840	830	670	330	290	180	130	789
1942	350	2910	2070	4090	6790	6350	6540	2220	2640	1760	848	908	3123
1943	274	1370	3820	4150	1650	2760	3330	5260	5050	2640	534	441	2607
1944	324	357	395	496	1130	4160	5980	3670	2910	486	324	308	1712
1945	294	299	790	1360	2460	9630	18200	14400	13400	6760	5300	1510	6200
1946	4220	4580	2430	6600	7410	6410.	2030	10070	5310	1140	1210	509	4327
1947	384	1900	4030	3390	2160	1300	5560	5980	2340	3180	399	267	2574
1948	245	1100	1940	6060	4190	6480	7510	2440	1250	1930	604	322	2839
1949	212	892	3670	10200	16300	9640	8400	1230	3170	1660	671	561	4717
1950	3130	2970	4200	18200	17300	8180	8160	8480	3620	1360	1220	2380	6766
1951	1150	1910	2350	5970	7730	8510	4420	1820	1770	4880	1750	2170	3703
1952	1130	5900	11000	8660	5530	8400	7530	2970	964	422	414	300	4435
1953	156	173	1530	1370	2860	7000	3920	4220	1240	769	373	194	1984
1954	111	114	227	1290	1440	1480	1380	2590	2090	764	254	135	990
1955	162	198	956	2520	994	4440	6840	3170	1710	944	367	144	1870
1956	195	246	392	585	6490	4250	1790	2120	1420	678	296	195	1555
1957	134	161	553	1730	5680	4470	11910	13660	13100	7720	4660	805	5382
1958	840	9580	6950	7780	4340	7660	10100	10200	2500	3010	3610	854	5619
1959	497	1330	2800	2330	5690	4650	2450	2130	1600	755	424	486	2095
1960	809	1210	2380	4240	3090	3420	3310	3820	2320	935	578	382	2208
1961	239	511	2010	1350	1400	8010	7300	10500	4610	1470	593	347	3195
1962	212	964	2450	4820	6540	7950	7790	2870	805	583	363	1430	3065
1963	615	456	507	795	586	3092	2780	1565	3046	708	500	404	1255
1964	198	235	492	594	695	9410	7700	2250	694	505	585	916	2023
1965	832	608	2360	2950	4230	3380	5080	1640	1630	1000	403	2490	2217
1966	2510	934	864	8900	5150	3500	3880	9490	4170	1220	1040	554	3518
1967	693	576	2350	2170	2800	3210	1540	4370	1240	1530	579	917	1831
1968	716	507	3690	4900	4570	3430	8220	7240	2270	798	714	474	3127
1969	370	607	3100	5570	10500	3630	8110	2960	1600	788	571	470	3190
Mean	798	1479	2464	4330	4891	5368	5951	4966	3062	1748	1013	724	3065

Note: Regulated Condition

Table 46 - Observed Mean Discharge, in c.f.s., Right Hand Chute of Little River at Rivervale, Ark., Sta 7-0466

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1948	260	1100	1590	3690	3450	5120	6360	2150	1090	1240	757	611	2286
1949	394	1280	3010	8660	14700	7390	7370	1720	3210	1750	1050	793	4278
1950	4940	1960	3830	19000	18400	7320	8290	5000	2880	1980	1740	2340	6474
1951	1090	2410	3310	6850	7310	6540	3120	1840	1610	3860	1240	928	3343
1952	717	2400	8760	10700	5920	8630	5700	1980	1360	668	860	397	4009
1953	234	334	858	1180	2280	5330	3500	4190	1940	887	400	176	1777
1954	152	183	351	1060	1570	1250	1390	1680	1460	508	381	136	844
1955	161	259	657	1450	1020	2630	4330	2350	2240	1330	637	303	1448
1956	257	305	386	450	6410	3410	1730	1610	1240	727	390	291	1435
1957	184	219	339	1250	4660	2610	6640	7780	9360	6570	4140	1860	3802
1958	1990	11600	8250	5920	3970	7460	7030	7190	2340	2310	1340	926	5028
1959	692	1200	1080	2230	4420	3040	1520	1080	1310	810	584	554	1544
1960	728	1200	2110	2400	2340	3190	2200	2440	2200	1620	1860	1660	1997
1961	1020	1670	1640	1150	1680	6530	6000	9050	3460	1650	1010	512	2949
1962	332	1850	4200	5390	4260	10740	6160	2990	1690	1200	747	1860	3453
1963	1110	802	684	763	572	3444	1408	1279	2028	922	740	479	1187
1964	214	257	369	381	520	10500	4080	1950	906	733	960	788	1806
1965	1040	764	3360	3930	6280	3150	5600	1680	1930	1220	541	2600	2676
1966	1630	995	949	8380	4170	1990	3320	8620	2350	1260	1420	819	2993
1967	886	613	2060	2120	1890	2970	1380	7020	2060	2460	1130	794	2116
1968	1300	1080	5910	2620	4380	3970	6660	6210	2090	1430	1090	580	3111
1969	585	656	3870	6540	11200	2920	7550	2210	1630	1160	696	465	3291
Mean	906	1507	2618	4370	5065	5007	4607	3729	2290	1651	1079	903	2811

Table 47 - Observed Mean Discharge, in c.f.s., Tyronza River
Near Tyronza, Ark., Sta 7-0476

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	115	340	420	1460	582	1100	317	210	573	144	152	86	460
1950	674	157	101	2340	2400	1110	289	1080	224	299	388	420	790
1951	140	634	490	1270	1260	412	301	175	382	954	145	223	841
1952	121	602	979	829	910	1060	356	261	145	98	135	90	465
1953	54	69	204	217	868	1060	460	2250	178	309	82	57	484
1954	52	48	59	874	317	166	110	327	139	43	36	37	184
1955	28	31	62	57	283	974	1430	451	175	273	58	49	323
1956	41	42	50	329	1710	214	379	286	210	72	60	66	288
1957	49	51	96	689	1360	127	885	1220	377	209	340	148	463
1958	466	2380	494	653	376	862	836	1600	137	396	102	190	708
1959	77	463	108	724	1360	262	131	100	435	207	84	74	335
1960	69	97	390	238	152	441	96	287	127	251	163	97	201
1961	104	367	395	239	795	863	737	543	338	141	94	74	391
1962	49	1170	1660	1000	654	1300	806	450	491	152	69	199	667
1963	66	54	46	43	44	673	67	627	232	68	49	45	168
1964	25	31	31	34	53	1280	1030	352	75	86	77	98	264
1965	49	263	1050	628	993	713	816	107	229	402	105	520	490
1966	77	93	62	560	856	93	576	950	113	80	132	141	310
1967	61	134	699	328	118	383	132	544	147	835	206	96	307
1968	114	76	628	403	121	578	1090	874	147	101	91	80	359
1969	57	286	655	786	797	205	791	141	102	101	207	92	352
Mean	115	340	420	652	762	661	554	611	237	249	132	137	421

Table 48 - Observed Mean Discharge, in c.f.s., St. Francis River at Latitude
of Wittsburg, Ark., Sta 7-0479.02

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1942	540	1890	2180	6040	9850	12680	13970	7560	3850	3270	1480	1730	5420
1943	890	1610	4770	5660	3860	6170	8420	7730	9190	4520	1410	1020	4604
1944	740	780	950	1240	4570	10340	17400	10960	5190	1640	1000	810	4635
1945	650	690	2610	6920	6680	20460	38220	28560	28590	17740	6310	3360	13399
1946	7610	9440	7150	19780	18060	16640	8020	14580	15640	3470	2720	1620	10394
1947	1040	1970	6020	8610	4870	3800	8540	10510	7320	6870	1970	1120	5220
1948	1090	2840	4050	10880	11470	18380	17830	6750	3900	3800	2270	1280	7045
1949	880	2300	6090	20960	34390	26130	23210	5040	8050	4720	2840	1940	11379
1950	9750	6990	9300	37920	45760	29920	20170	17400	10440	4840	3940	6930	16947
1951	3130	6050	8610	16300	17900	20300	10100	5580	5450	10100	5190	3500	9351
1952	2810	7040	24500	25600	16600	21400	19100	7900	3550	1880	2020	1410	11151
1953	941	1060	3000	3300	7660	16800	12200	16400	5290	3290	1430	845	6018
1954	652	508	877	5620	5090	3960	3840	5660	3460	1990	812	460	2533
1955	484	480	1560	3850	3480	9170	18950	8460	6670	4090	2100	1050	5029
1956	830	880	1260	2110	2090	13610	5680	5220	3830	2400	1290	934	3345
1957	644	559	1120	3720	14770	8700	21360	22600	31000	17350	10930	4790	11462
1958	4300	23270	29940	20260	12710	17110	24260	25960	6540	7520	5420	3340	15053
1959	2150	3880	4580	6470	16640	11900	5320	3810	3760	2730	1800	1690	5394
1960	1800	2840	5020	7600	6970	8510	6760	6380	6050	3850	2610	1980	5031
1961	1420	2510	4580	4180	5720	18160	20050	22560	12840	5045	2909	2312	8523
1962	2192	3327	6154	13830	16440	30530	22120	9510	4570	3280	1750	4390	9840
1963	2870	2090	1850	2151	1847	8760	5040	4740	6902	2700	1750	1399	3508
1964	749	839	1095	1290	1560	21000	19200	7360	2630	1990	2490	2140	5195
1965	2640	2500	8960	10600	15600	10800	15500	5070	4900	3490	1740	6700	7375
1966	5330	2650	2460	19000	14100	8490	8920	26100	9750	3380	4760	2430	8948
1967	2100	1780	5670	6830	5240	8400	4270	13900	7090	6820	3410	2240	5646
1968	2615	2065	11230	10910	11570	8837	19510	19720	6563	3315	2496	1801	8378
1969	1480	1990	8970	15100	31900	9340	18000	7750	4170	3440	2200	1510	8821
Mean	2192	3327	6154	10597	12408	14296	14313	11631	8171	5045	2909	2312	7844

Note: Regulated Conditons

Table 49 - Observed Mean Discharge, in c.f.s., L'Anguille River at Palestine, Ark., Sta 7-0479.5

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1950	1670	787	2890	6530	7850	3640	1890	3240	74	163	554	2130	2618
1951	762	1180	1370	3310	2740	1730	1280	403	643	1310	698	623	1337
1952	214	565	2790	2390	2270	3110	1850	372	26	5	82	161	1153
1953	19	91	574	536	2670	4200	2590	6590	366	143	75	81	1495
1954	32	5	174	2400	2240	661	274	1270	34	0	19	67	598
1955	26	0	40	319	711	2430	3960	1760	1860	629	224	109	1006
1956	76	13	93	98	7110	2030	791	747	115	134	87	182	956
1957	12	123	283	628	4430	1430	4870	3140	1780	345	546	417	1500
1958	604	5580	3150	2240	1490	2260	2060	5930	289	1160	285	1030	2173
1959	411	839	391	1620	4310	1800	559	45	226	332	252	298	924
1960	140	138	585	1140	1160	1950	202	240	508	1070	346	480	663
1961	254	522	581	940	1060	3170	3540	1320	411	153	163	266	1032
1962	59	1200	4740	3340	2420	4480	2490	431	328	416	208	1210	1777
1963	823	81	15	35	136	2060	301	206	1150	180	175	266	452
1964	2	0	65	101	408	3400	2930	697	66	295	455	1120	795
1965	409	216	2090	2380	3600	1550	1710	164	267	155	224	2030	1233
1966	587	12	4	1280	3110	650	860	3220	216	194	1710	682	1044
1967	151	82	344	1540	655	1410	200	1790	858	1640	728	560	830
1968	260	21	2010	1550	1650	1710	1860	2990	449	164	216	574	1121
1969	426	107	1870	1060	5170	1010	1500	214	113	108	371	290	1020
Mean	332	553	1149	1793	2788	2272	1843	1662	539	432	363	605	1186

Table 50 - Observed Mean Discharge, in c.f.s., Cache River at Patterson, Ark., Sta 7-0775

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1948	110	1620	1670	2400	2420	3690	1970	327	1130	631	282	118	1364
1949	66	888	2220	5650	6350	4490	3490	360	970	821	259	198	2147
1950	2830	876	2300	8810	8820	4170	1980	2340	1180	628	788	1450	3014
1951	454	1620	1500	2480	3610	2580	1320	891	509	1170	917	495	1462
1952	227	1540	5080	6040	3060	4450	2650	643	276	126	170	140	2034
1953	67	114	2060	943	2430	4210	2280	2860	282	249	95	67	1305
1954	59	40	67	1480	1230	640	658	1050	176	58	75	68	467
1955	73	23	150	729	298	2250	2240	1440	1090	203	152	81	727
1956	167	62	92	189	6730	2040	321	237	167	176	76	80	861
1957	12	46	73	736	4170	1120	4650	5350	3220	877	1170	381	1817
1958	165	5300	6170	2820	1750	2920	3040	4910	407	1030	455	328	2441
1959	118	1080	233	830	3070	1730	319	190	417	197	176	189	712
1960	136	851	1730	1380	1510	2050	290	1970	1010	1200	421	235	1065
1961	170	551	878	624	524	4130	4230	3690	1170	227	212	162	1381
1962	70	870	3130	3220	2270	5650	3780	949	218	314	192	1620	1857
1963	244	93	79	111	69	2283	151	261	1151	147	109	143	403
1964	33	23	38	37	172	4790	3750	714	111	215	475	612	914
1965	926	504	2470	2530	3080	1780	2860	264	747	478	305	2210	1513
1966	859	136	326	5620	3080	1340	1790	5010	1420	244	1920	266	1834
1967	162	104	549	1160	392	1170	157	1510	1180	1510	312	311	710
1968	235	106	2060	775	1410	1690	2730	2640	826	302	163	558	1125
1969	215	101	1780	3170	6400	1450	2870	609	171	322	194	169	1454
Mean	334	748	1529	2351	2857	2756	2160	1737	810	506	405	449	1391

Table 51 - Observed Mean Discharge, in c.f.s., Bayou DeView at Morton, Ark., Sta 7-0777

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1940	5	9	24	34	856	157	1270	174	17	7	19	26	217
1941	6	84	384	372	158	44	435	23	4	25	83	70	141
1942	13	97	581	700	1590	923	1340	147	234	11	127	63	486
1943	9	140	426	340	78	1450	292	32	29	4	0.5	0	233
1944	8	5	24	96	1866	1725	1862	114	40	3	2	20	480
1945	24	51	1013	1514	1072	2658	1767	512	2173	173	61	110	927
1946	318	1172	562	2310	1240	786	609	1950	648	43	43	21	809
1947	116	579	670	834	26	135	997	177	83	56	0	5	307
1948	88	931	733	721	1590	2530	699	6	765	72	98	27	688
1949	2	942	1550	2860	1960	1560	1230	58	508	131	113	43	913
1950	1800	107	1640	3920	3630	1420	844	1030	69	120	398	884	1322
1951	385	971	896	1420	1490	591	584	92	356	676	595	247	692
1952	28	593	2270	2200	935	1740	733	64	8	0	44	78	724
1953	2	32	750	670	1270	1820	590	1940	28	284	22	40	621
1954	9	0	21	1210	646	209	100	555	40	0	40	34	239
1955	35	0	135	423	400	1350	1350	510	518	209	56	55	420
1956	5	0	14	114	3840	467	170	157	110	65	30	13	415
1957	0	17	31	964	1098	236	1980	1650	1150	257	464	46	660
1958	197	2810	1490	990	456	1320	816	2390	44	325	90	265	933
1959	8	434	46	597	1610	1085	85	16	260	155	167	157	380
1960	78	171	656	772	714	798	79	238	279	585	357	155	407
1961	68	373	380	516	415	1650	1620	576	308	161	176	93	530
1962	0	490	1480	1320	775	1760	918	168	161	101	88	889	679
1963	68	0	0	17	3	1351	24	292	676	34	73	85	219
1964	0	0	0	13	173	2100	1140	289	59	99	400	386	388
1965	99	262	741	1000	1580	414	960	95	163	150	117	1070	554
1966	52	24	30	1800	1050	278	662	1650	80	214	1020	244	592
1967	31	13	221	406	128	704	189	872	169	682	260	248	327
1968	32	24	864	410	640	763	678	1380	193	87	183	411	472
1969	81	88	894	379	1660	521	1170	135	67	103	157	82	445
Mean	119	347	618	964	1098	1085	840	576	308	161	176	196	541

Table 52 - Modified Mean Discharge, in c.f.s., White River at
Clarendon, Ark., Sta 7-0778

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1924	14600	16800	35600	40600	28000	24600	25700	32500	40300	26200	16700	13400	26300
1925	13700	13300	14700	15600	19000	26000	21400	16600	13900	12400	11100	14300	16000
1926	34000	58000	34700	29600	38300	36000	39600	20700	15100	14200	18900	20100	29800
1927	20300	24500	36700	55500	93100	62700	112100	54100	63600	59700	52400	60800	55100
1928	58600	58400	54500	68500	39700	35300	75800	81100	97300	93500	51900	29800	62100
1929	16400	18900	41700	41800	78500	78600	80600	108000	91700	51300	16400	13800	52900
1930	14000	18300	20400	67000	70600	42700	21800	40100	19700	14200	13600	14300	29500
1931	16200	16300	15900	15000	27000	37100	32100	23500	17200	15400	14700	12300	20200
1932	13100	14100	30500	67800	58600	30000	32800	15700	13100	14400	12500	12400	26200
1933	13200	13900	19300	47700	36400	28900	43800	55500	47400	13500	14800	14500	29600
1934	14600	11900	21000	20000	15100	26400	61700	17000	13800	13000	13200	14500	20200
1935	14200	15700	17300	27900	31600	63200	71500	59300	62900	58200	30200	13600	38800
1936	14200	17000	20500	14000	14500	16700	22600	14300	13400	14500	13600	14700	15800
1937	15500	20200	18000	72200	82100	33000	24700	28000	20600	17200	13500	13000	29500
1938	17600	17500	20400	28800	56900	65000	65800	55300	40700	16700	15700	11600	34200
1939	11900	16100	13700	19800	60000	67100	56500	56900	42700	18400	12800	12200	32100
1940	11700	12000	12400	13600	18100	18800	30000	31100	14200	14200	14300	13400	17000
1941	13000	14500	18100	20300	23100	17000	22500	15600	14500	14200	13000	13800	16600
1942	16000	21400	19300	31500	36100	39900	48400	40300	22500	14900	17300	17800	27000
1943	14500	19200	24700	49700	22400	23700	30900	43600	56500	45800	14100	11700	29800
1944	11700	11600	11800	13300	24200	35800	44000	51400	17000	11800	12300	12400	21400
1945	11600	12800	17700	27100	25900	85300	138700	64200	94700	67300	46500	49800	53460
1946	54700	44700	20200	51000	52400	59800	45700	51800	67400	27100	17200	14500	42100
1947	13800	26200	44700	38800	22400	18300	31000	43500	26500	15200	12900	12600	25500
1948	13200	19400	23300	32600	29800	50600	41000	21400	17700	25900	14300	9400	24900
1949	12980	16400	26600	49800	110500	84800	75700	22300	25100	27000	17500	17500	40000
1950	32800	28300	33300	90000	108400	78600	61600	61900	54800	38600	29500	37900	54300
1951	26600	27400	20200	34700	41000	55800	48800	37100	22100	33200	37100	23800	34000
1952	20100	36100	67000	69700	46800	59200	67800	45700	19100	12900	13400	12000	39200
1953	12400	14800	26200	21900	33100	52300	49000	51300	22600	13800	9900	9900	26400
1954	11500	10800	10600	18200	21100	18200	19100	24500	10000	9200	8700	11200	14400
1955	8400	13100	14400	19800	16700	28400	40300	26600	30400	17600	11200	11000	19800
1956	9800	8800	9100	9500	52200	30700	17600	21000	14900	13800	11300	10400	17300
1957	9000	10000	11600	15100	40400	28000	67800	88700	79500	56900	54400	40700	41800
1958	26100	53500	52500	34500	28400	39300	67300	91100	36000	25200	27400	17400	41600
1959	13600	24100	26900	21000	38100	38900	26400	15100	18000	12100	10700	10600	21300
1960	13200	17100	25600	37400	32300	35200	22600	36000	41400	22000	12400	9900	25400
1961	8200	8500	17600	16100	19300	51000	82400	85900	46500	31200	24400	10100	33400
1962	8180	10100	29800	32500	42200	58100	49200	32500	12700	13100	10500	15200	26200
1963	13000	9000	10400	9930	9890	26800	14100	10750	23550	12130	10000	7420	13100
1964	7000	7280	8070	6200	8800	50500	59100	24300	10600	10200	11200	9700	17700
1965	10000	8800	19200	24100	34900	29800	40800	23200	20200	15900	13600	18500	21600
1966	14800	10000	11000	52500	47000	42400	29100	79100	30300	17100	20400	14700	30700
1967	10700	10200	10900	17300	18100	21100	15500	32600	19300	19500	14100	9700	16600
1968	11800	16300	36900	41800	47900	39300	66100	78800	40200	26700	17300	13000	36300
1969	17200	21900	47200	74100	112800	60800	66600	46100	19800	14900	12400	11000	42100
1970	10500	9800	12400	27700	18300	29800	28700	63900	21100	14300	20800	16600	22800
Mean	16390	19250	24140	34760	41110	42160	47580	43400	33250	24390	18770	16570	30040

Note: Regulated Conditions

Table 53 - Observed Mean Discharge, in c.f.s., Arkansas River at Little Rock, Ark., Sta 7-2635

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928	84000	23800	45800	37500	33600	34300	105000	57000	118000	49200	38200	10600	53100
1929	6410	30600	50300	66600	37100	54900	125000	174000	105000	56500	10300	8940	60400
1930	10300	11120	17400	41830	56730	17620	7524	112700	42060	12380	4613	12390	28780
1931	13516	9057	27370	7684	40470	26270	33480	36060	26940	9958	12300	5402	20570
1932	10700	26100	45900	126000	76200	29700	23800	15000	33800	53000	15400	5520	38400
1933	4110	3230	27100	48600	16300	40700	58900	102000	22100	7580	19100	51700	35600
1934	18120	16030	17440	26530	8532	25080	51860	22930	8072	3000	1141	25990	18740
1935	18640	25730	23470	37530	18960	110700	51080	151100	268900	54850	8831	13820	65400
1936	13340	25650	48540	10500	7086	10510	6040	12660	19700	5100	1777	6860	14010
1937	54950	22460	14960	91760	54240	28040	31550	26580	60950	14490	9117	19850	35700
1938	7508	14610	18680	38630	137600	40190	99610	75000	93970	17250	17110	8787	46590
1939	4207	8369	3487	11870	43390	30820	68950	38560	22520	20400	6076	3379	21770
1940	1770	2199	2562	2871	4919	4771	26540	25250	14860	13440	12380	18460	10820
1941	3235	10960	29030	50790	52730	23030	79110	52010	88790	19790	12050	41970	38350
1942	141400	173000	44150	30350	49500	43680	145300	117500	80260	45480	21990	42960	77830
1943	30250	54290	42980	51690	20770	27870	45880	290300	99600	24020	7752	4817	58730
1944	10550	10030	7414	12930	41370	100700	124500	124300	66300	17090	13010	15580	45240
1945	37280	12520	46650	25950	63550	211100	274000	108500	136600	59470	18510	24720	84780
1946	115800	17830	11500	77830	81460	49480	50230	102300	48450	24250	5886	6606	49240
1947	9701	52980	84660	19610	9939	19650	121000	140500	68070	27560	8848	6919	47590
1948	5685	7444	17550	30670	54590	85190	39410	35800	53870	135500	74120	14010	44710
1949	7151	11370	19620	84850	150500	73220	49210	128900	111700	58360	16170	17480	58420
1950	22800	12600	17820	79890	78260	35370	20910	110400	49200	80870	118500	77720	58740
1951	25500	10610	8405	20130	66570	52120	32520	72970	81330	117500	34110	48450	52490
1952	27560	71760	40520	36400	31230	80860	92110	47650	22670	6202	4937	3772	38730
1953	2386	7629	21620	13240	18460	53400	67560	75950	10710	13900	8526	4948	24940
1954	3398	6240	6340	14090	13950	6829	10700	63520	14530	5095	2917	1622	12470
1955	3344	4432	5211	16170	24380	44990	29450	35110	36860	18270	6271	5761	19150
1956	25660	5584	4945	5475	42780	9617	9238	14370	8832	4032	2789	1356	11100
1957	1168	1760	3891	10060	32160	25690	135200	216600	262400	101800	37850	25520	71120
1958	13630	41090	20260	22990	19880	88910	86080	92780	39830	94810	45270	22200	49240
1959	11020	18950	11440	10450	22400	48460	39250	46430	33080	56300	32430	15680	28900
1960	167400	46810	50110	63370	51160	56290	48100	120300	54620	39610	26010	21640	62590
1961	11530	21420	30810	16600	20050	54220	79420	175100	68870	59610	37410	69580	53930
1962	53830	82910	69490	42340	50130	49830	47460	17330	39230	19170	14620	29660	42870
1963	38060	22020	20040	15980	9301	30980	10730	16450	8323	14220	8504	8779	17060
1964	3774	4052	3237	2383	6189	26480	36560	25690	19280	9465	5318	12860	12920
1965	5976	22190	23510	21960	27480	27240	68640	30570	51750	30860	11530	28500	29050
1966	23250	7376	6096	17130	36280	18050	32000	48260	14720	8225	12560	10660	19450
1967	7345	5755	5381	5566	5921	8781	22770	55040	20610	49690	22520	17580	17350
1968	21410	34380	43030	26940	63090	77860	89340	92310	61800	26570	22770	14350	47710
1969	12300	31700	71200	65900	97700	64400	72500	84000	67200	50600	20900	15000	54450
1970	31010	16750	18970	28830	16940	38230	79200	99990	49920	16940	8291	17080	35270
Mean	26100	24300	26300	34200	41500	46200	63400	80700	60600	37000	19000	19100	39820

Note: Unregulated conditions. Future flows will be regulated.

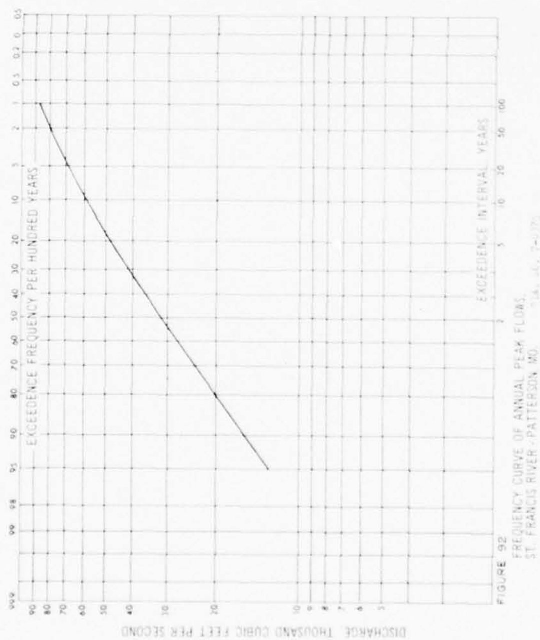


FIGURE 92
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
ST. FRANCIS RIVER - PATTERSON, MO.

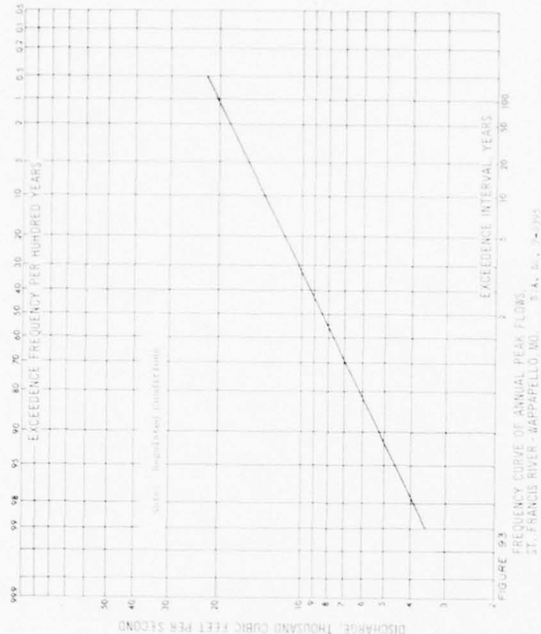


FIGURE 93
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
ST. FRANCIS RIVER - WAPPAPELLO, MO.

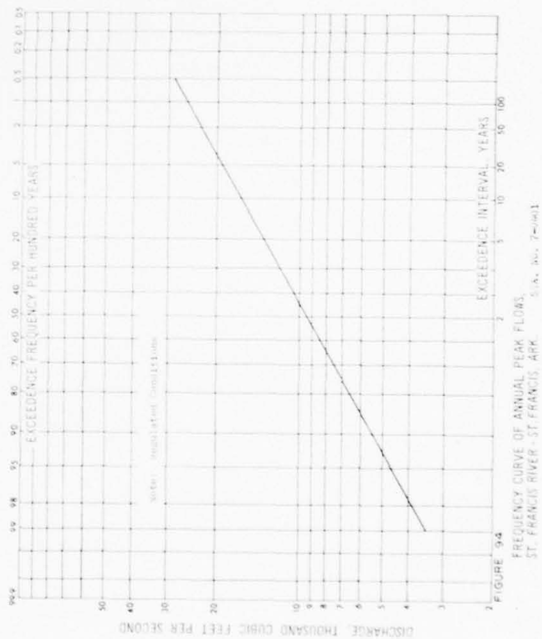


FIGURE 94
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
ST. FRANCIS RIVER - ST. FRANCIS, ARK.

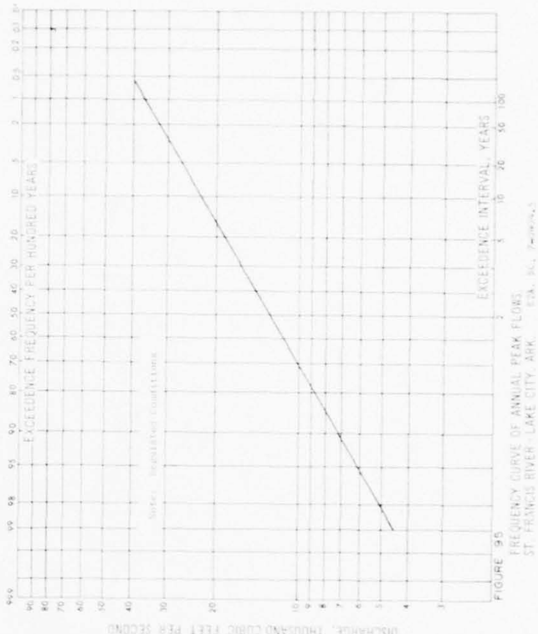


FIGURE 95
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
ST. FRANCIS RIVER - LAKE CITY, ARK.

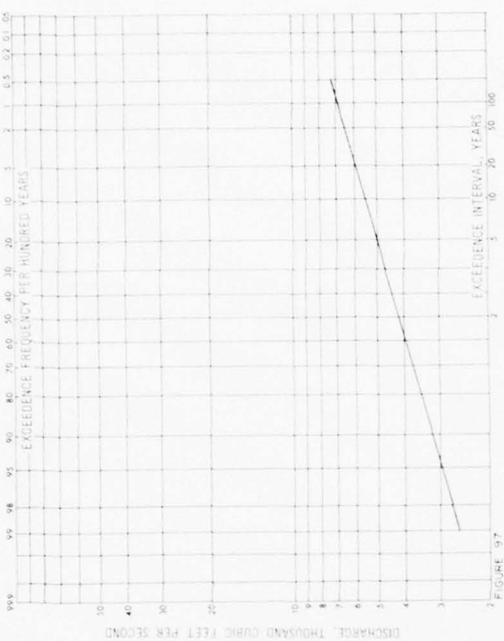


FIGURE 97
FREQUENCY CURVE OF ANNUAL PEAK FLOWS
TYRONZA RIVER - TYRONZA, ARK.

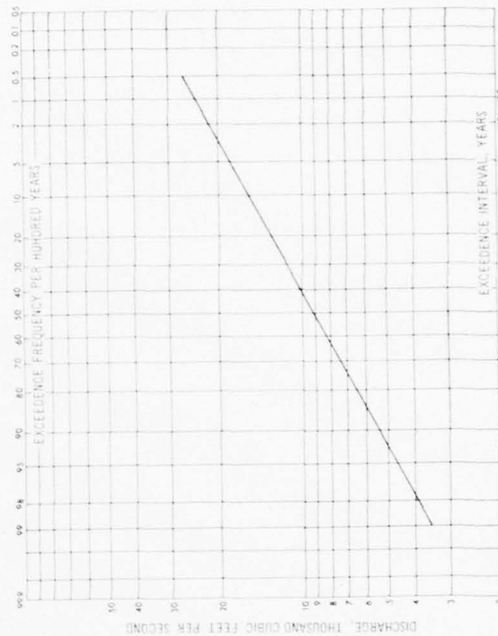


FIGURE 99
FREQUENCY CURVE OF ANNUAL PEAK FLOWS
L'ANGUILLE RIVER - PALESTINE, ARK.

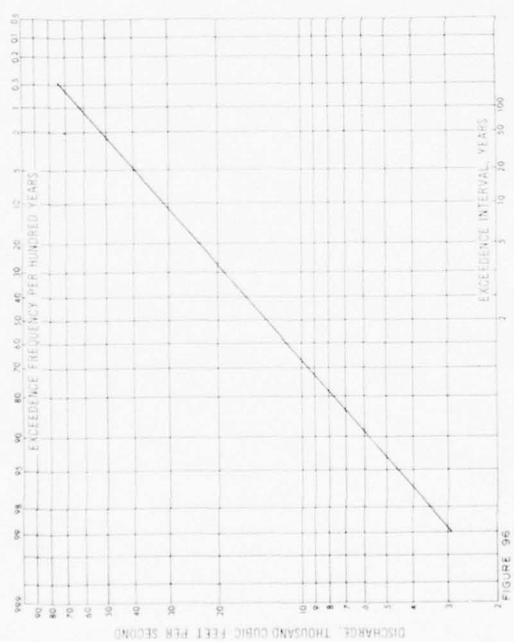


FIGURE 96
FREQUENCY CURVE OF ANNUAL PEAK FLOWS
RIGHT HAND CHUTE LITTLE RIVER - RIVERVALE, ARK.

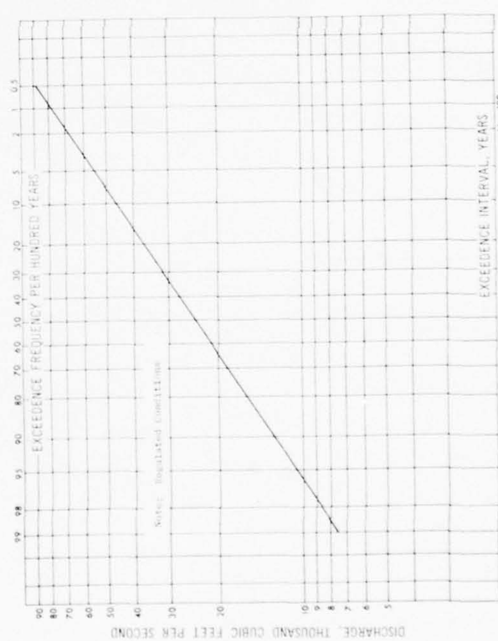


FIGURE 98
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
ST. FRANCIS RIVER - LATITUDE OF WITTSBURG, ARK.

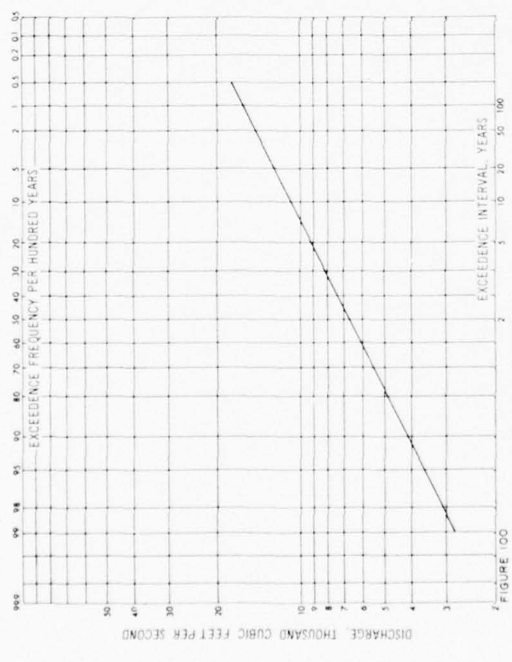


FIGURE 100
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
CACHE RIVER - PATTERSON, ARK. STA. NO. 7-0775

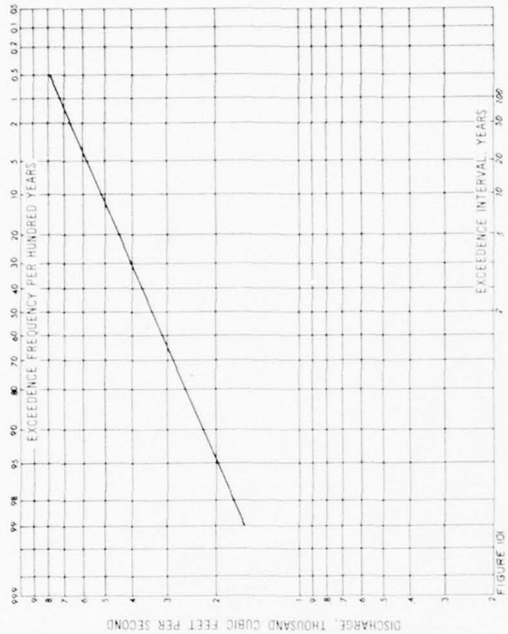


FIGURE 101
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
BAYOU DE VIEW - MORTON, ARK. STA. NO. 7-0777

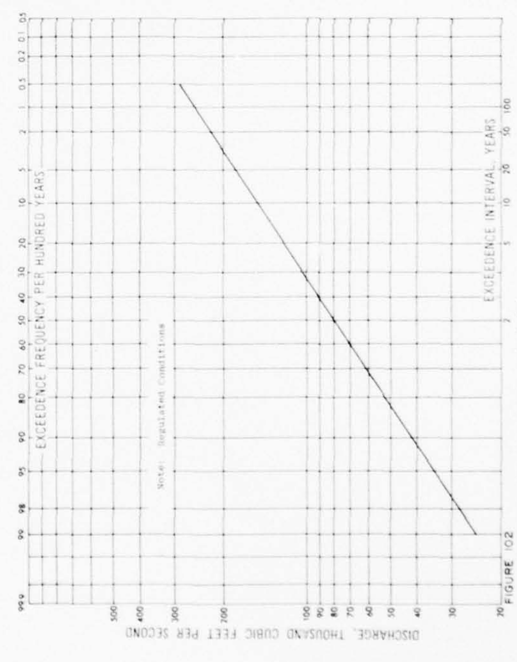


FIGURE 102
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
WHITE RIVER - CLARENDON, ARK. STA. NO. 7-0778

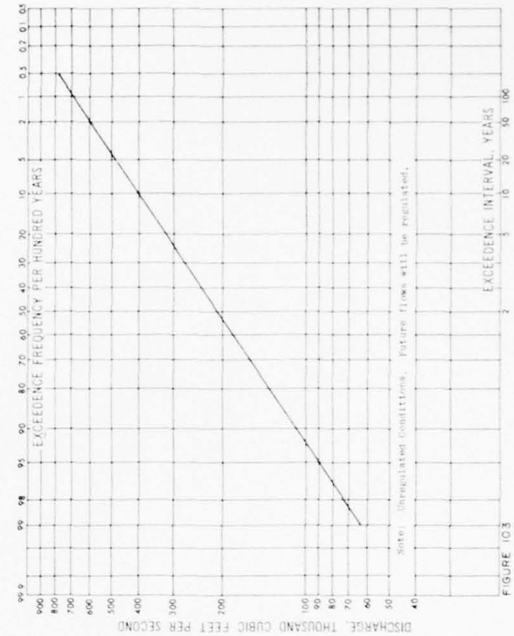


FIGURE 103
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
ARKANSAS RIVER - LITTLE ROCK, ARK. STA. NO. 7-[illegible]

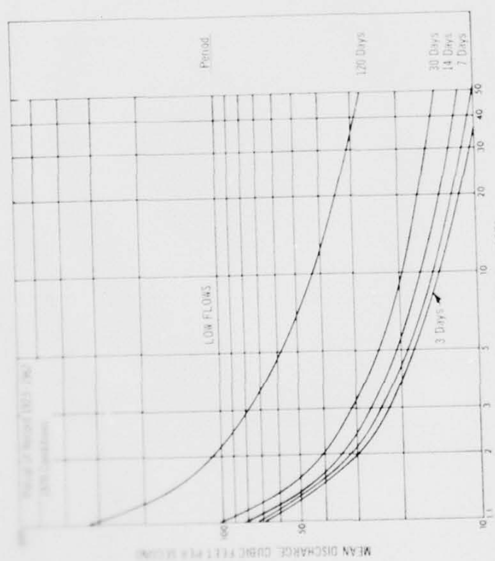


FIGURE 104
Frequency Curves, St. Francis River near Patterson, Missouri STA. NO. 7-0375

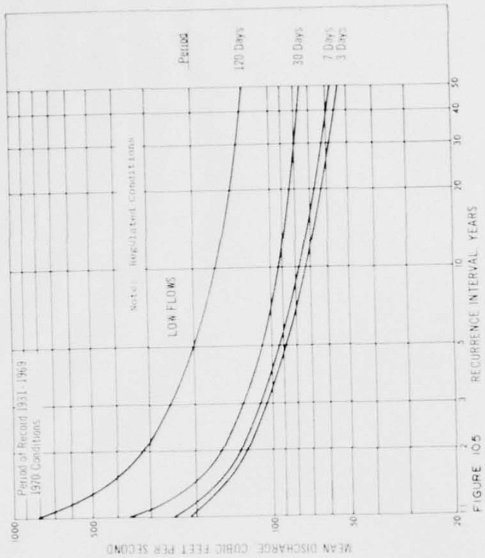


FIGURE 105
Frequency Curves, St. Francis River at St. Francis, Arkansas STA. NO. 7-0401

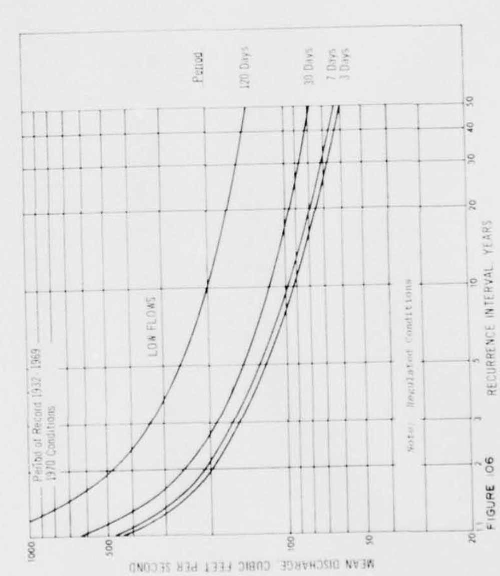


FIGURE 106
Frequency Curves, St. Francis River at Lake City, Arkansas STA. NO. 7-0405

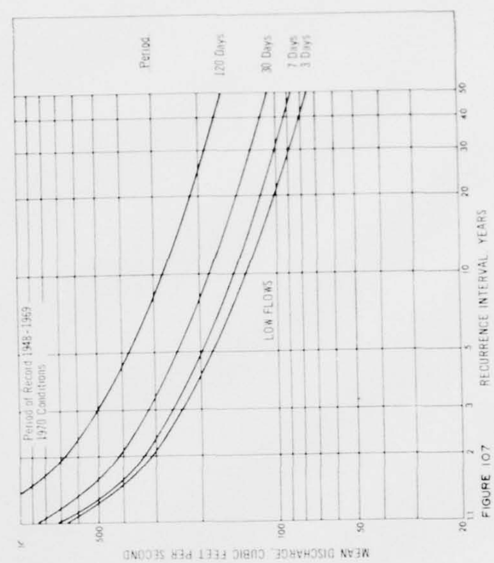


FIGURE 107
Frequency Curves, Right Hand Chute Little River at Riverdale, Arkansas STA. NO. 7-0440

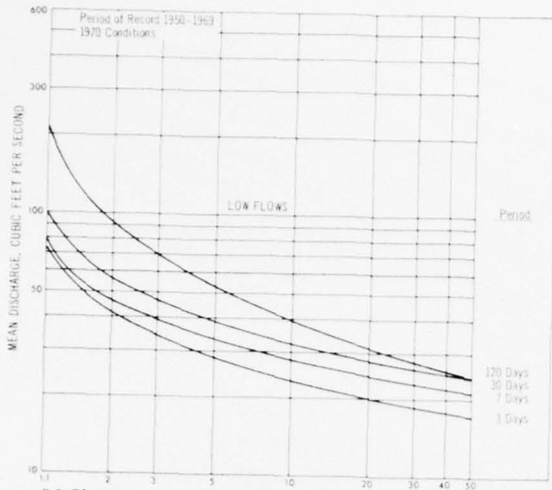


FIGURE 108

Frequency Curves, Tyronza River near Tyronza, Arkansas   STA. NO. 7-0476

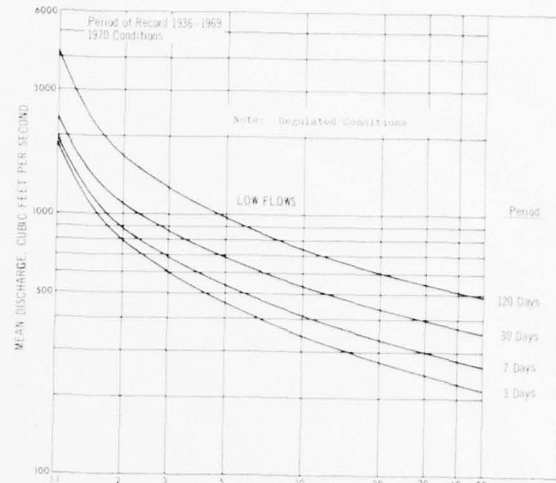


FIGURE 109

Frequency Curves, St. Francis River at Latitude of Wittsburg, Arkansas   STA. NO. 7-047.02

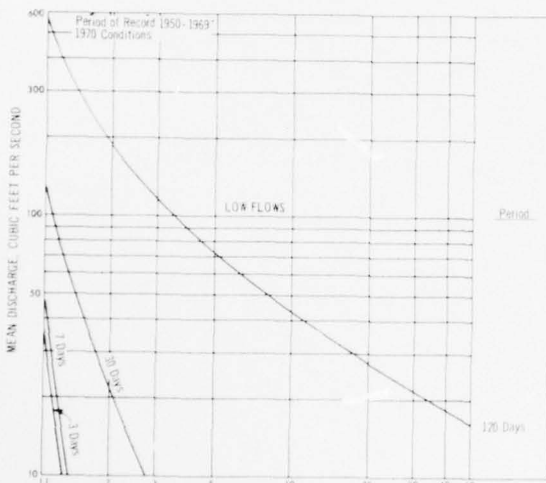


FIGURE 110

Frequency Curves, L'Anguille River at Palestine, Arkansas   STA. NO. 7-0479.5

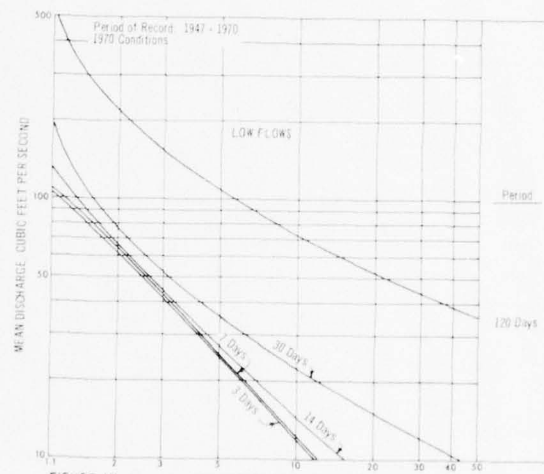


FIGURE 111

Frequency Curves, Cache River at Patterson, Arkansas   STA. NO. 7-0775

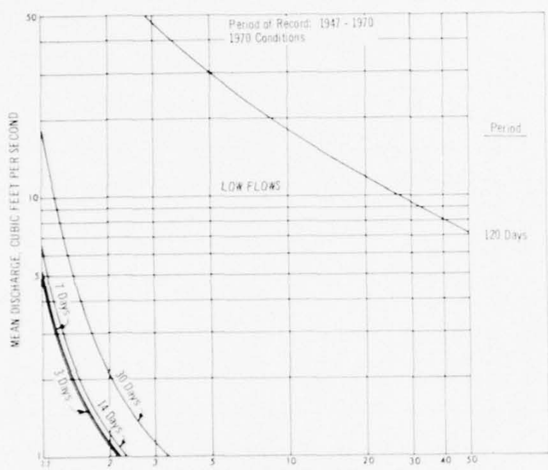


FIGURE 112

Frequency Curves, Bayou de View at Morton, Arkansas SSA. NO. 7-0777

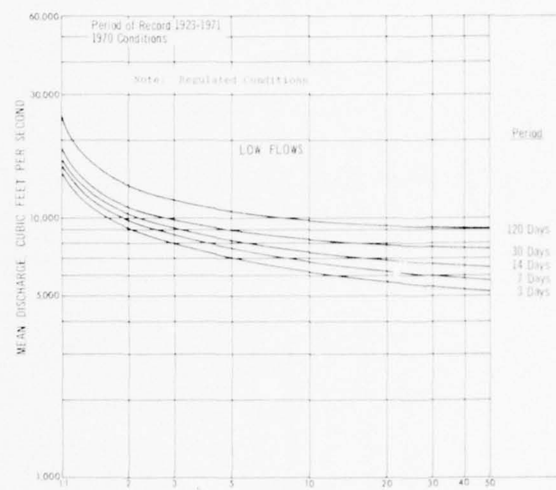


FIGURE 113

Frequency Curves, White River at Clarendon, Arkansas SSA. NO. 7-0776

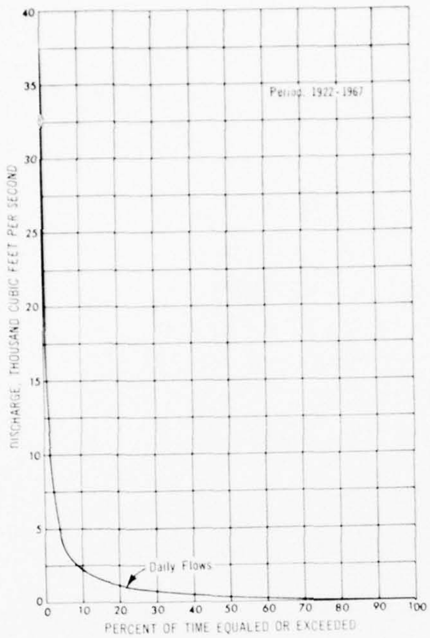


FIGURE 114

Duration Curve, St. Francis River near
Patterson, Missouri STA. NO. 7-0375

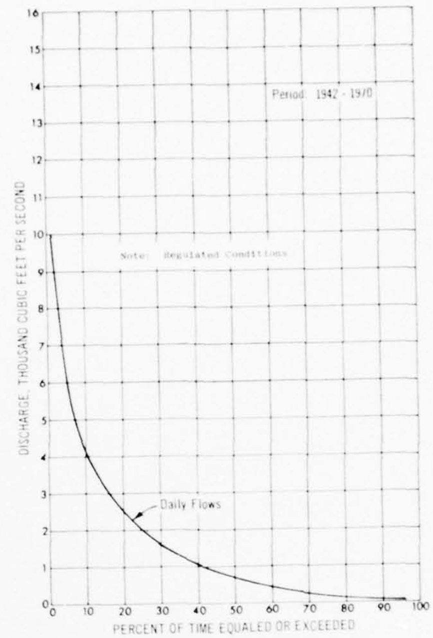


FIGURE 115

Duration Curve, St. Francis River at
Wappapello, Missouri STA. NO. 7-0395

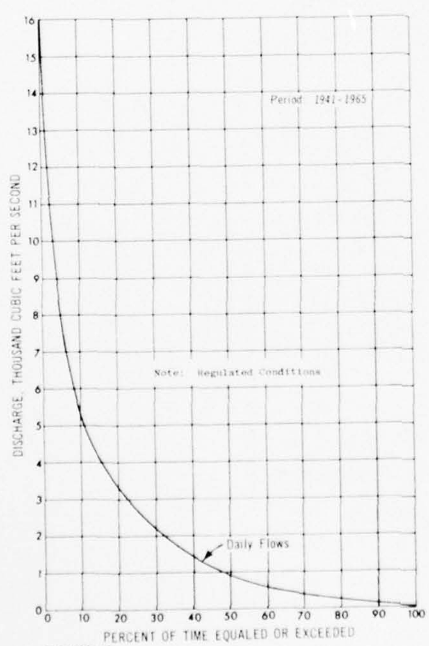


FIGURE 116

Duration Curve, St. Francis River at
St. Francis, Arkansas STA. NO. 7-0401

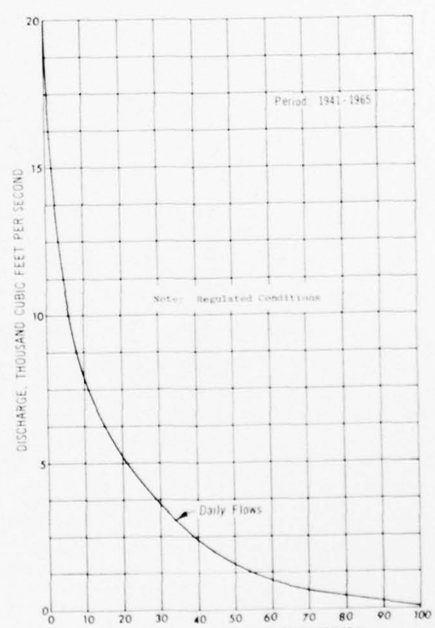


FIGURE 117

Duration Curve, St. Francis River at
Lake City, Arkansas STA. NO. 7-0404.5

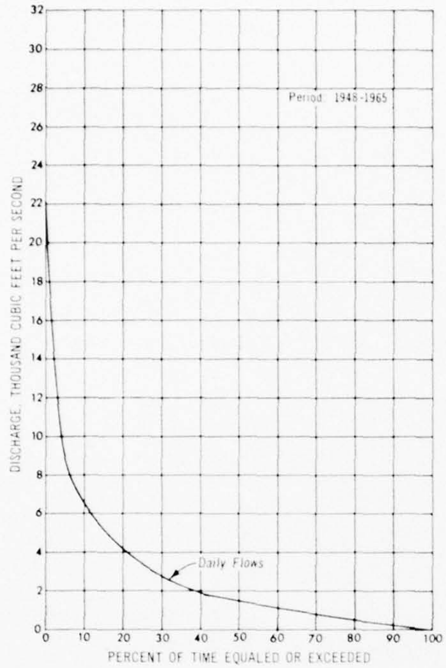


FIGURE 118

Duration Curve, Right Hand Chute of Little River
Rivervale, Arkansas STA. NO. 7-0466

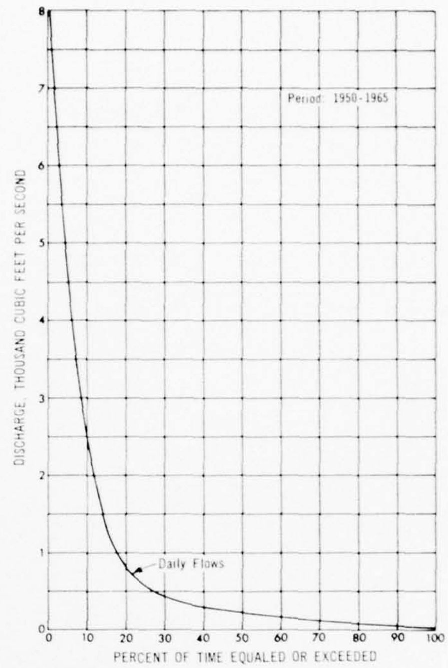


FIGURE 119

Duration Curve, Tyronza River near
Tyronza, Arkansas STA. NO. 7-0476

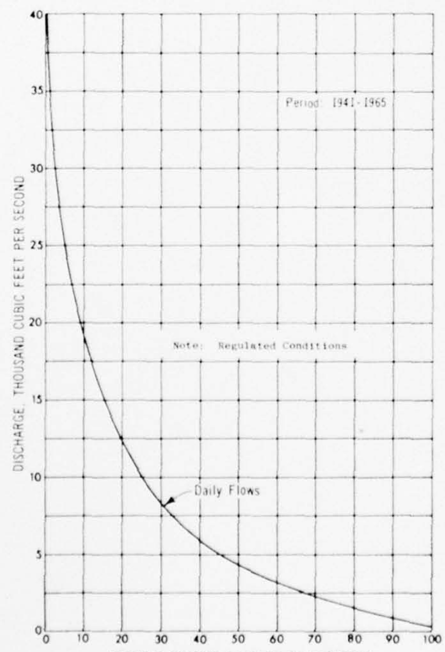


FIGURE 120

Duration Curve, St. Francis River at Latitude of
Wittsburg, Arkansas STA. NO. 7-0479.02

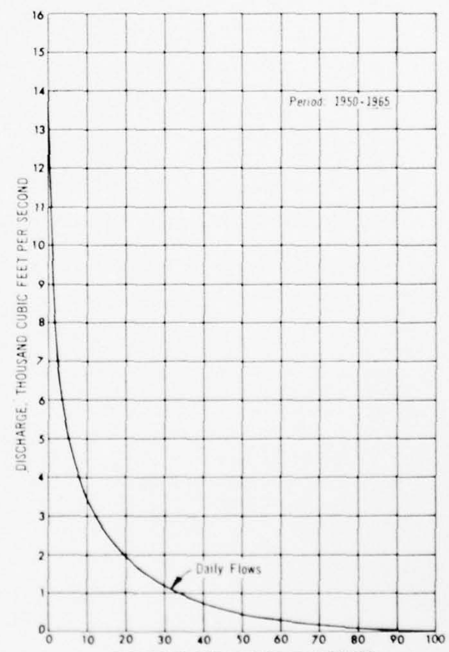


FIGURE 121

Duration Curve, L'Anguille River at
Palestine, Arkansas STA. NO. 7-0479.5

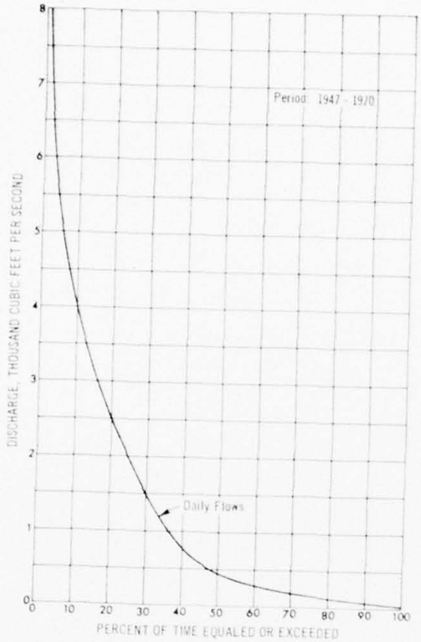


FIGURE 122

Duration Curve, Cache River at
Patterson, Arkansas STA. NO. 7-0775

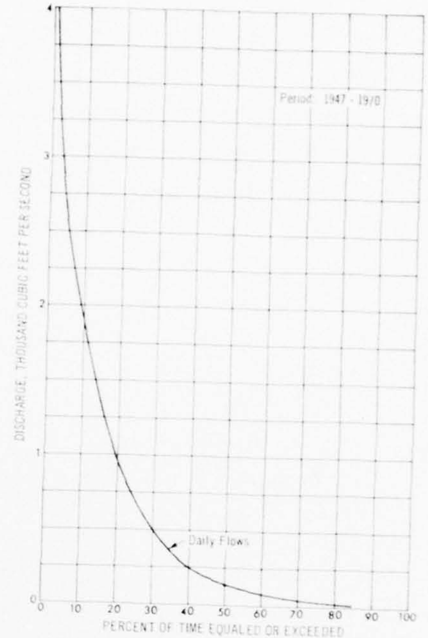


FIGURE 123

Duration Curve, Bayou de View at
Morton, Arkansas STA. NO. 7-0777

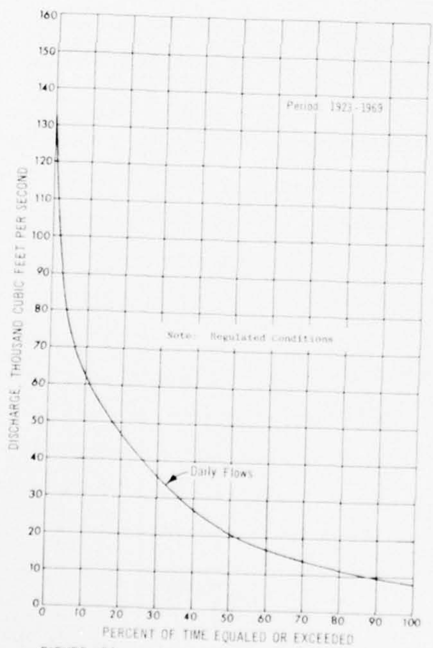


FIGURE 124

Duration Curve, White River at
Clarendon, Arkansas STA. NO. 7-0776

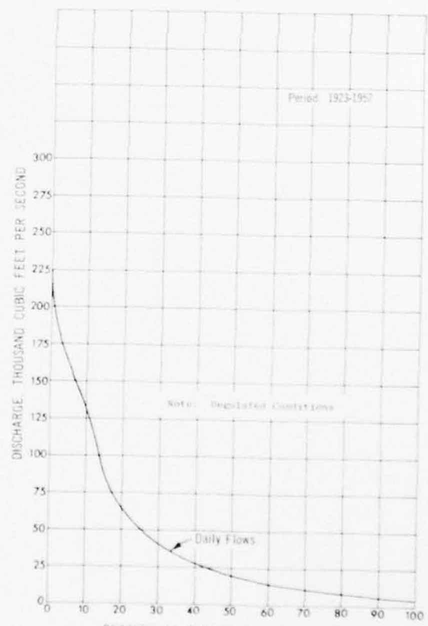


FIGURE 125

Duration Curve, Arkansas River at
Little Rock, Arkansas STA. NO. 7-[illegible]

Table 54 - Dependable Yield, St. Francis River near Patterson, Mo., Sta 7-0375

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	343	31.6
2	1940-41	458	42.2
3	1930-32	552	50.9
4	1953-56	563	51.9
5	1930-34	709	65.4
6	1962-67	758	69.9
7	1961-67	813	74.9
8	1960-67	828	76.4
9	1959-67	839	77.4
10	1959-68	876	80.8
50	1921-70	1,084	100.0

Table 55 - Dependable Yield, St. Francis River at Wappapello, Mo., Sta 7-0395 1/

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1954	584	37.9
2	1953-54	707	45.8
3	1954-56	766	49.7
4	1953-56	782	50.7
5	1952-56	1,003	65.1
6	1962-67	1,064	69.0
7	1959-65	1,130	73.3
8	1960-67	1,151	74.7
9	1959-67	1,160	75.2
10	1959-68	1,214	78.8
28	1942-69	1,541	100.0

1/ Regulated conditions.

Table 56 - Dependable Yield, St. Francis River at St. Francis, Ark., Sta 7-0401 1/

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	550	26.0
2	1953-54	962	45.5
3	1954-56	1,038	49.2
4	1953-56	1,059	50.1
5	1952-56	1,432	67.8
6	1962-67	1,542	73.0
7	1959-65	1,596	75.6
8	1960-67	1,652	78.2
9	1959-67	1,641	77.7
10	1959-68	1,717	81.3
29	1941-69	2,111	100.0

1/ Regulated conditions.

Table 57 - Dependable Yield, St. Francis River at Lake City, Ark., Sta 7-0404.5 1/

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	789	25.7
2	1954-55	1,430	46.7
3	1954-56	1,472	48.0
4	1953-56	1,600	52.2
5	1963-67	2,165	70.6
6	1959-64	2,307	75.3
7	1959-65	2,294	74.8
8	1960-67	2,412	78.7
9	1959-67	2,377	77.5
10	1959-68	2,452	80.0
29	1941-69	3,065	100.0

1/ Regulated conditions.

Table 58 - Dependable Yield, Right Hand Chute of Little River at Rivervale, Ark., Sta 7-0466

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1954	844	30.0
2	1954-55	1,146	40.8
3	1954-56	1,242	44.2
4	1953-56	1,376	48.9
5	1953-57	1,861	66.2
6	1951-56	2,143	76.2
7	1959-65	2,230	79.3
8	1953-60	2,234	79.5
9	1959-67	2,302	81.9
10	1954-63	2,369	84.3
22	1948-69	2,811	100.0

Table 59 - Dependable Yield, Tyronza River near Tyronza, Ark., Sta 7-0476

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1963	168	39.9
2	1963-64	216	51.3
3	1954-56	265	62.9
4	1963-66	308	73.2
5	1963-67	308	73.2
6	1963-68	316	75.1
7	1963-69	321	76.3
8	1960-67	350	83.0
9	1959-67	348	82.6
10	1959-68	349	82.9
21	1949-69	421	100.0

Table 60 - Dependable Yield, St. Francis River at the Latitude of Wittsburg, Ark., Sta 7-0479.02 1/

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1954	2,533	32.3
2	1954-55	3,781	48.2
3	1954-56	3,636	46.3
4	1953-56	4,231	53.9
5	1952-56	5,615	71.6
6	1951-56	6,238	79.5
7	1959-65	6,409	81.7
8	1959-66	6,727	85.8
9	1959-67	6,607	84.2
10	1959-68	6,783	86.5
28	1942-69	7,844	100.0

1/ Regulated conditions.

Table 61 - Dependable Yield, L'Anguille River at Palestine, Ark., Sta 7-0479.5

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1963	452	38.1
2	1963-64	624	52.6
3	1963-65	827	69.7
4	1963-66	881	74.3
5	1963-67	871	73.4
6	1963-68	913	76.9
7	1963-69	928	78.2
8	1960-67	978	82.5
9	1959-67	972	82.0
10	1959-68	987	83.2
20	1950-69	1,186	100.0

Table 62 - Dependable Yield, Cache River at Patterson, Ark., Sta 7-0775

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1963	403	29.0
2	1954-55	597	42.9
3	1954-56	685	49.2
4	1953-56	840	60.4
5	1953-57	1,035	74.4
6	1959-64	1,055	75.9
7	1959-65	1,121	80.6
8	1953-60	1,174	84.4
9	1959-67	1,154	83.0
10	1959-68	1,151	82.8
22	1948-69	1,391	100.0

Table 63 - Dependable Yield, Bayou DeView at Morton, Ark., Sta 7-0777

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	141	26.1
2	1940-41	179	33.1
3	1940-42	281	52.0
4	1940-43	269	49.8
5	1940-44	311	57.6
6	1940-45	414	76.6
7	1963-69	428	79.2
8	1940-47	450	83.2
9	1959-67	453	83.8
10	1959-68	455	84.1
30	1940-69	541	100.0

Table 64 - Dependable Yield, White River at Clarendon, Ark., Sta 7-0778 1/

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1963	13,100	43.6
2	1963-64	15,400	51.3
3	1954-56	17,170	57.1
4	1953-56	19,480	64.8
5	1963-67	19,940	66.4
6	1962-67	20,980	69.8
7	1959-65	22,670	75.5
8	1960-67	23,090	76.8
9	1959-67	22,890	76.2
10	1959-68	24,230	80.6
47	1924-70	30,040	100.0

1/ Regulated conditions

Table 65 - Dependable Yield, Arkansas River at Little Rock, Ark., Sta 7-2635 1/

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1940	10,820	27.2
2	1963-64	14,990	37.6
3	1954-56	14,240	35.8
4	1953-56	16,920	42.5
5	1963-67	19,170	48.1
6	1962-67	23,120	58.1
7	1962-68	26,630	66.9
8	1963-70	29,160	73.2
9	1962-70	30,680	77.1
10	1931-40	30,560	76.8
43	1928-70	39,820	100.0

1/ Unregulated conditions. Future flows will be regulated.

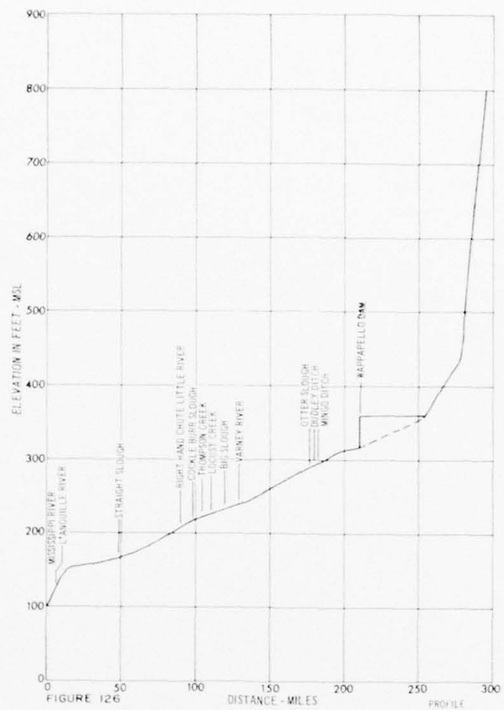


FIGURE 126

PROFILE
ST. FRANCIS RIVER

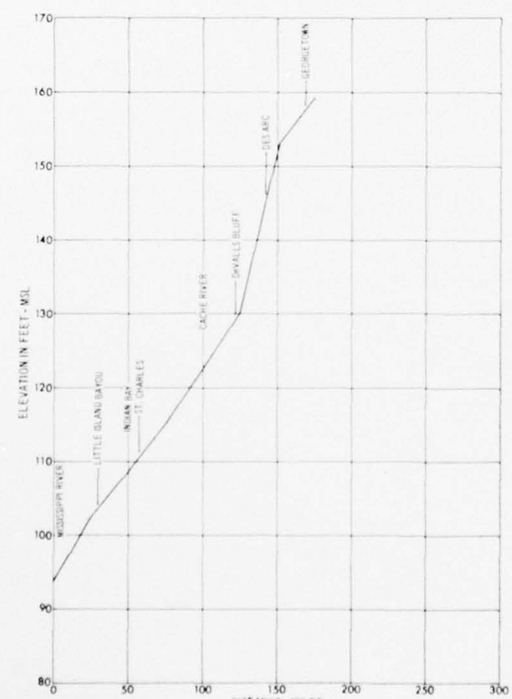


FIGURE 127

PROFILE
WHITE RIVER

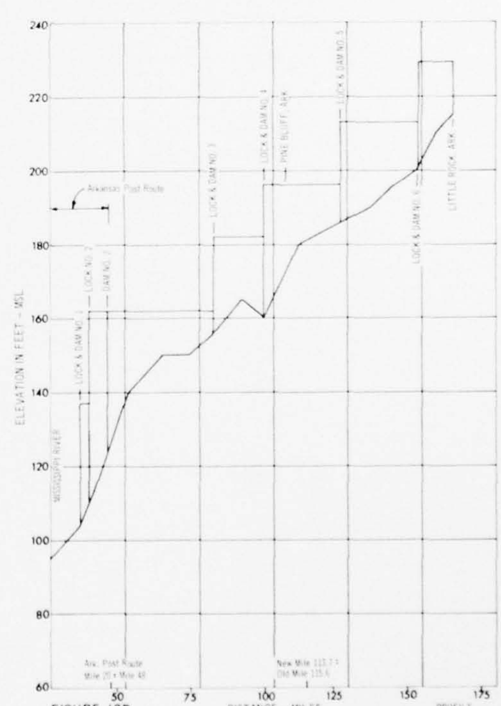


FIGURE 128

PROFILE
ARKANSAS RIVER

Table 66 - Chemical Analyses of Low-Flow Surface Waters in WRPA 2 in the Lower Mississippi Region, Milligrams Per Liter

Geologic units in drainage basin above sampling station	Date sampled	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
		07043050 Ditch 24 at Peavy, Mo. (drainage area, 35.6 sq mi)																	
Paleozoic rocks and Cretaceous deposits	9-13-60	22	8.5	0.00	56	27	8.3	1.4	294	11	12	0.3	0.2	270	250	10	471	7.6	5
	11-14-62	31	14	.00	60	26	8.2	1.3	296	14	13	.2	.6	287	256	14	498	7.2	5
		07042400 Ditch 1 near Matthews, Mo. (drainage area, 62.0 sq mi)																	
Cretaceous deposits, Tertiary deposits, and alluvium	6-27-61	100	12	0.06	40	14	9.0	1.1	184	35	7.0	0.0	0.7	199	158	23	316	7.6	5
		07077050 Big Creek near Jonesboro, Ark. (drainage area, 51.1 sq mi)																	
Pliocene(?) deposits	9-22-60	1.1	6.8	0.01	13	5.0	9.6	2.9	87	5.5	6.0	0.3	0.5	91	57	0	151	7.4	15
	8-15-62	.52	9.3	.04	12	6.8	9.1	2.5	83	5.3	5.5	.1	.2	92	58	5	142	7.3	10
		07074400 Village Creek at Walnut Ridge, Ark. (drainage area, 34.3 sq mi)																	
Quaternary terrace deposits and alluvium	8-14-62	2.6	17	0.06	36	14	7.5	4.2	182	9.2	3.5	0.1	0.4	182	148	0	304	7.9	8
		07074700 Village Creek at Newport, Ark. (drainage area, 270 sq mi)																	
	9-28-60	--	1.8	0.01	20	4.8	7.2	4.0	93	6.2	5.0	0.2	0.9	96	70	0	162	7.2	22
	10-26-60	26	2.8	.03	18	4.3	6.0	4.6	78	6.6	4.5	.2	1.0	93	62	0	152	7.0	22
		07040400 Locust Creek Ditch near Paragould, Ark. (drainage area, 73.5 sq mi)																	
	9-28-60	2.7	6.4	0.06	41	9.9	12	2.6	175	20	9.5	0.3	0.5	194	143	4	309	7.8	10
	8-15-62	1.6	16	.00	63	15	11	1.5	266	16	7.5	.1	.1	261	219	0	393	8.5	5
		07040100 Lateral Ditch 2 near East Prairie, Mo. (drainage area, 77.3 sq mi)																	
Quaternary alluvium	9-14-60	9.4	11	0.00	52	12	7.2	2.0	210	12	2.8	0.5	1.4	209	179	2	346	7.3	7
		07046520 Main Ditch 1 near Deering, Mo. (drainage area, 66.4 sq mi)																	
	9-15-60	22	13	0.00	61	19	13	2.9	308	21	5.3	0.2	0.4	293	243	0	480	7.7	9
	11-13-62	26	21	.00	73	19	15	2.8	328	25	6.0	.3	.8	330	273	4	550	7.1	5

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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Table 66 - Chemical Analyses of Low-Flow Surface Waters in WRPA 2 in the Lower Mississippi Region, Milligrams Per Liter--Continued

Geologic units in drainage basin above sampling station	Date sampled	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
	07040900 Main ditch 2 near Malden, Mo. (drainage area, 15.2 sq mi)																		
Quaternary alluvium	9-13-60	12	12	0.00	38	6.8	7.4	1.7	40	19	5.5	0.4	0.6	160	123	8	258	7.1	5
	6-26-61	50	13	.00	39	7.2	7.4	1.2	146	16	5.0	.0	.1	161	127	8	257	7.6	7
	11-12-62	38	26	.01	36	7.5	8.0	1.5	133	19	6.2	.2	.5	170	121	12	266	7.1	5
	07043100 Lake Slough near Gulin, Mo. (drainage area, 78.0 sq mi)																		
	9-13-60	6.9	18	0.00	58	13	4.5	1.3	248	6.4	3.0	0.4	0.3	227	198	0	372	7.5	7
	11-12-62	9.3	30	--	56	14	4.4	1.3	236	7.2	2.8	.2	.2	232	197	4	375	7.0	5
	07046550 Buffalo ditch near Arbyrd, Mo. (drainage area, 38.7 sq mi)																		
	9-15-60	17	14	0.00	53	10	8.0	1.5	204	18	5.0	0.9	0.7	211	173	6	346	7.3	7
	6-26-61	64	20	.08	60	16	6.6	1.3	186	23	6.0	.0	.4	204	166	14	317	7.7	5
	07047980 Fifteen Mile Bayou near West Memphis, Ark. (drainage area, 51.0 sq mi)																		
	10-25-60	7.4	7.1	0.00	62	18	8.1	4.1	266	26	4.0	0.3	1.0	262	228	6	433	7.2	20

aIncludes equivalent of 12 mg/l of carbonate (CO_3)

GROUND WATER

Quaternary surface deposits of WRPA 2 are underlain by Precambrian, Paleozoic, Cretaceous, and Tertiary rocks. The Precambrian and Paleozoic rocks are exposed only in small areas in the uplands. Cretaceous and Tertiary rocks which underlie the Mississippi River alluvium and Quaternary terrace deposits are exposed in small areas along the western side of the Mississippi alluvial plain and on Crowleys Ridge.

The Quaternary deposits, principally the Mississippi River Valley alluvial aquifer, supply most of the ground water pumped for irrigation and industrial purposes in WRPA 2; the Sparta Sand and the Memphis aquifer supply most of the remainder. Other aquifers capable of yielding large quantities of ground water are the McNairy and Nacatoch Sand in the northern part of the area; the lower Wilcox aquifer in the northern and central part; the Cockfield Formation in the southern part; and the Carrizo Sand in the central and southern part (figure 129).

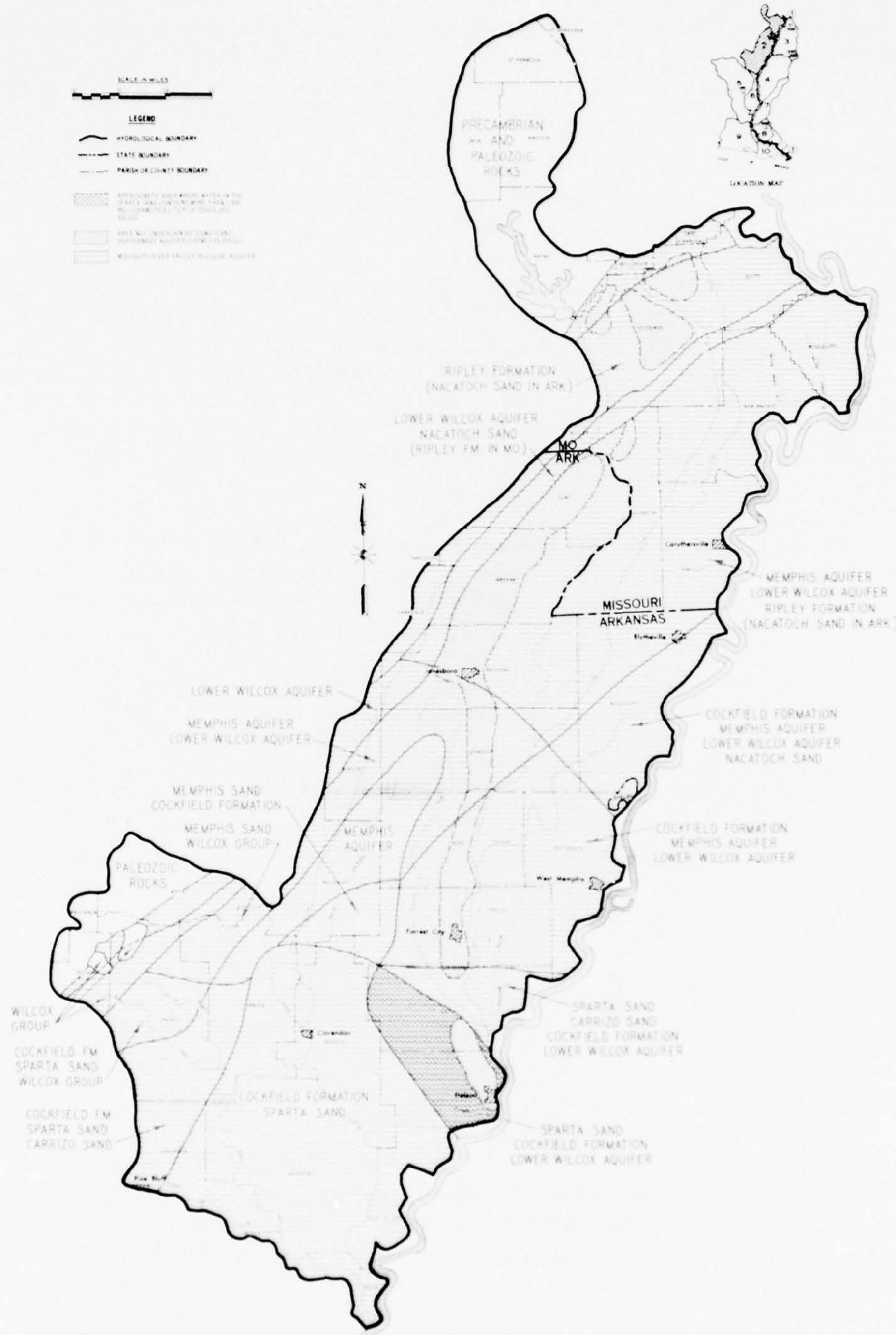
Most of the recharge to Quaternary aquifers is from precipitation on the surface. The underlying artesian aquifers in much of the area are recharged in the uplands to the east and northeast in WRPA 3. The movement of ground water in the artesian aquifers is westward from the uplands to areas of lower hydraulic head in the alluvial plain. Some recharge occurs in the small areas where the artesian aquifers crop out in the western part of the area. The recharge-discharge relation between the Quaternary aquifers and the underlying artesian aquifers is dependent on hydraulic head differences; the movement of ground water will be into the aquifer with the lower head.

Paleozoic Aquifers

The Potosi dolomite of Cambrian age is the only aquifer in the Ozark Plateau of Missouri that is commonly capable of large yields to wells; however, several Cambrian and Ordovician sandstone and dolomite aquifers are capable of yielding 10 to 75 gpm to individual wells [159]. Larger supplies may be obtained from wells open in several water-bearing zones.

The Cambrian and Ordovician rocks generally yield hard calcium-magnesium bicarbonate water. The dissolved-solids content of water from the Potosi dolomite is generally less than 300 mg/l, and the iron content is less than 0.3 mg/l.

In the Arkansas Valley, ground water is available in limited quantities from Paleozoic rocks of low permeability [17]. Yields of wells are mostly less than 10 gpm, and the quality of the water varies considerably from place to place.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOLOGIC SOURCES OF GROUND WATER

WRPA 2

FIGURE 129

Ground water in the Ouachita Mountains principally occurs in joints, fractures, and bedding plane separations [2]. The coefficient of transmissibility for aquifers in the Ouachita Mountains is generally less than 1,000 gpd per foot, and well yields are less than 10 gpm.

Cretaceous Aquifers

McNairy and Nacatoch Sand

The McNairy Sand (in Missouri) and Nacatoch Sand (in Arkansas) contain fresh water in about 40 percent of WRPA 2, or in approximately the northern one-half of the part of WRPA 2 lying in the Coastal Plain. The aquifer is used mostly in the western and northern parts of the area where it contains fresh water and occurs at shallow depths. The utilization of the aquifer is slight because sufficient water for present needs is available from shallower aquifers in Tertiary and Quanternary deposits.

On the basis of aquifer tests in Tennessee and Kentucky [13], the coefficient of transmissibility for the McNairy Sand in Missouri is probably 10,000 to 20,000 gpd per foot for thicker sands; however, in some places the formation does not include sands thick enough for even small wells. Wells made at favorable locations are reported to yield more than 1 mgd. The Nacatoch Sand in northern Arkansas is the same unit as the McNairy Sand in Missouri and is similar in hydraulic characteristics.

In Missouri, water from the McNairy Sand changes from a calcium bicarbonate type near the outcrop area to a sodium bicarbonate type down the dip. At some places in the northern part of the area, the high dissolved-solids content of water in the McNairy Sand at some localities may be the result of upward movement of water from Paleozoic rocks.

Water withdrawn from the Nacatoch and McNairy Sands in WRPA 2 is estimated to total about 3 mgd. Flowing wells probably account for most of the water withdrawn from the aquifer. The potential yield of the Cretaceous aquifers in WRPA 2 is estimated to be about 40 mgd (table 23).

Tertiary Aquifers

Lower Wilcox Aquifer

The Wilcox Group contains thick extensive beds of sand in the subsurface in the northern two-thirds of WRPA 2. A zone of interconnected sand beds in the lower part of the Wilcox Group, the lower Wilcox aquifer, attains a maximum thickness of about 400 feet in southeastern Missouri. Because of its favorable hydraulic characteristics, areal extent, and good quality water, the lower Wilcox is a large potential source of ground water.

Moderate to large yields can be expected from wells tapping the lower Wilcox aquifer in WRPA 2. The largest yield reported for such wells is 2,000 gpm at West Memphis, Ark. [50]. Results of pumping tests in Arkansas and nearby parts of Tennessee indicate coefficients of transmissibility ranging from 100,000 to more than 150,000 gpd per foot and permeabilities of the magnitude of 1,000 gpd per square foot.

The largest withdrawals from the lower Wilcox are in the Memphis, Tenn.,-West Memphis, Ark., area where about 20 mgd is withdrawn. Although Memphis is not in WRPA 2, the cone of depression in the lower Wilcox aquifer covers an appreciable area west of the Mississippi River. The total withdrawal in WRPA 2 (excluding withdrawals at Memphis) is estimated to be about 12 mgd.

Water in the lower Wilcox aquifer is generally a soft sodium bicarbonate type. The dissolved-solids content of the water is less than 500 mg/1 in about 90 percent of the area where the aquifer contains fresh water, and the water is commonly suitable for general use without treatment. The estimated potential yield of the lower Wilcox aquifer in WRPA 2 is about 35 mgd.

Carrizo Sand

The Carrizo Sand is virtually undeveloped in WRPA 2. The aquifer contains fresh water in a narrow zone extending westward from the Mississippi River south of Memphis and south to Pine Bluff (figure 62). North of this area the Carrizo Sand becomes the lower part of the Memphis aquifer (figure 63).

The Carrizo Sand averages about 100 feet in thickness in WRPA 2. On the basis of aquifer tests made in the Meridian-upper Wilcox aquifer, the equivalent of the Carrizo in Mississippi, the coefficient of transmissibility for the Carrizo is estimated to be about 50,000 gpd per foot in WRPA 2.

Water in most of the Carrizo Sand in WRPA 2 is moderately mineralized (500 to 1,000 mg/1) in the downdip areas for which data are available; however, the dissolved-solids content at shallower depths in the western part of the area is less than 500 mg/1.

Withdrawals from the Carrizo Sand in WRPA 2 are negligible. The aquifer is a reserve source of water capable of yielding about 34 mgd for uses where the water quality can be tolerated.

Cane River Formation

The Cane River Formation in Arkansas is a marine clay in the southern part of WRPA 2. The unit becomes sandy northward, merging into the middle part of the Memphis aquifer.

Memphis Aquifer

The Memphis aquifer is not used extensively in WRPA 2; however, because of its excellent hydraulic characteristics, areal extent, and thickness, it has the greatest potential of any aquifer except the Mississippi River alluvial aquifer for meeting future requirements for water. The principal sources of recharge to the aquifer are precipitation on the outcrop area in the uplands in WRPA 3 and leakage from the overlying Mississippi River Valley alluvial aquifer in WRPA 2. Additional recharge occurs where the aquifer crops out in Crowleys Ridge. As water levels in the aquifer decline, the Mississippi River alluvial aquifer will become a significant source of recharge.

Results of aquifer tests made in Kentucky and Tennessee show that the average transmissibility in WRPA 2 is probably in the 200,000 gpd per foot range. In much of the area, the Memphis aquifer is capable of yielding 2,000 gpm or more to large wells.

Water from the Memphis aquifer is of good quality and low in dissolved solids and soft. In some places treatment for removal of iron and pH adjustment are needed. Softening may be required in areas where the aquifer is replenished by water from the Mississippi River alluvial aquifer.

The present withdrawals from the Memphis aquifer in WRPA 2 total about 20 mgd. A larger quantity of water, perhaps 30 to 40 mgd, moves from WRPA 2 into WRPA 3 as a result of withdrawals at Memphis, Tenn. The potential yield of the Memphis aquifer in WRPA 2 is about 400 mgd.

Sparta Sand

The Sparta Sand is the most extensive artesian aquifer in the Lower Mississippi Region. The formation crops out in Mississippi, Tennessee (where it is equivalent to the upper part of the Memphis aquifer), and Arkansas, and it forms much of the pre-Quaternary surface under the Mississippi Alluvial Plain. The hydrology of the Sparta has been studied perhaps more than any other aquifer in the region [50, 81, 87]. The Sparta is recharged by precipitation on the outcrop and by leakage from the overlying Mississippi River Valley alluvial aquifer in some areas of heavy pumping. The aquifer has been the principal source of ground water for all uses except irrigation in the southern part of WRPA 2 and water level declines have been large in some areas.

Transmissibility values for the Sparta Sand are not available for locations in WRPA 2. Based on pumping tests made in adjacent areas, the coefficient of transmissibility in WRPA 2 probably ranges from 20,000 to 50,000 gpd per foot. The Sparta Sand is generally capable of supporting well yields of 1 mgd or more.

Water from the Sparta Sand in areas where the aquifer is now used is generally a soft sodium bicarbonate type; however, in part of Monroe

and Lee Counties, Ark., the water is a sodium chloride type and has a high dissolved-solids content. In some areas, the water requires treatment for iron removal.

Withdrawals from the Sparta Sand amount to about 25 mgd in WRPA 2. The potential yield of the aquifer in the area is about 96 mgd. Much of the water level decline in the Sparta in WRPA 2 is a result of withdrawals outside the area, especially at Pine Bluff, Ark.

Cockfield Formation

The Cockfield Formation does not crop out in WRPA 2 but is overlain everywhere by younger deposits. The Cockfield is composed of up to 200 feet of irregularly bedded fine sand and clay. The formation is present in its maximum thickness in the southern part of WRPA 2 where it is overlain by the Jackson Group. In the remainder of the area where it occurs, the Cockfield is overlain by and hydraulically connected to the Mississippi River alluvium.

Data describing the hydraulic characteristics of the Cockfield Formation are not available for WRPA 2. On the basis of hydraulic characteristics determined in adjoining areas, the transmissibility of the aquifer probably ranges from a maximum of about 50,000 gpd per foot in the southern part of WRPA 2 to less than 10,000 gpd per foot in the central part of the area.

Water in the Cockfield Formation in WRPA 2 is a sodium bicarbonate type except in areas where the aquifer is connected to and recharged by the Mississippi River alluvial aquifer. In these areas, the water is hard, a calcium bicarbonate type similar to water in the alluvium.

The Cockfield is important as a source of ground water for domestic, stock, and other small wells because it is the shallowest aquifer below the Mississippi River Valley alluvial aquifer in the southern part of WRPA 2. The aquifer is also capable of meeting requirements for small municipal and industrial water supplies. The total withdrawal in WRPA 2 is less than 5 mgd; however, the aquifer can supply about 20 mgd in the area.

Quaternary Aquifers

Mississippi River Valley Alluvial Aquifer

All of WRPA 2 except the Crowleys Ridge, Ozark Plateau, and Arkansas Valley areas is blanketed by Quaternary alluvium. The alluvial deposits are divided into two areas by Crowleys Ridge. South and west of Crowleys Ridge lies an area of predominately older alluvium. Both areas are parts of the Mississippi River Valley alluvial aquifer although Crowleys Ridge is a hydrologic boundary. The alluvium, averaging about 100 feet in thickness, is composed of a lower sand and gravel

unit and an upper unit of silt, clay, and, in places, fine sand.

The alluvial sand and gravel deposits form an excellent aquifer. Large wells, commonly yielding 2,000 gpm or more, can be made anywhere that a sufficient thickness of alluvium occurs. Exceptions are in areas underlain by clay "plugs" or unusually thin sand and gravel sections. The average coefficient of transmissibility for the Mississippi River alluvium in WRPA 2 is about 180,000 gpd per foot, and values range from about 70,000 gpd per foot in Jackson County to about 300,000 gpd per foot in Crittenden County.

Ground water from the Mississippi River Valley alluvial aquifer generally is a hard to very hard calcium bicarbonate or calcium magnesium bicarbonate type, moderately mineralized, and containing excessive iron. The water temperature is near the mean annual air temperature, which ranges from about 58° F in the northern part of WRPA 2 to about 64° F in the southern part.

The Mississippi River Valley alluvial aquifer is the largest potential source of ground water in WRPA 2, capable of yielding more than 3,000 mgd. In much of the area, the withdrawals are replaced each winter and spring by precipitation; however, in some areas the upper clay and silt are too impermeable to allow replacement of large withdrawals. The present pumpage from the alluvial aquifer in WRPA 2 is about 1,100 mgd, about one-half of which is used for irrigation in the Grand Prairie Region in Arkansas.

Effects of Ground Water Withdrawals and Management Considerations

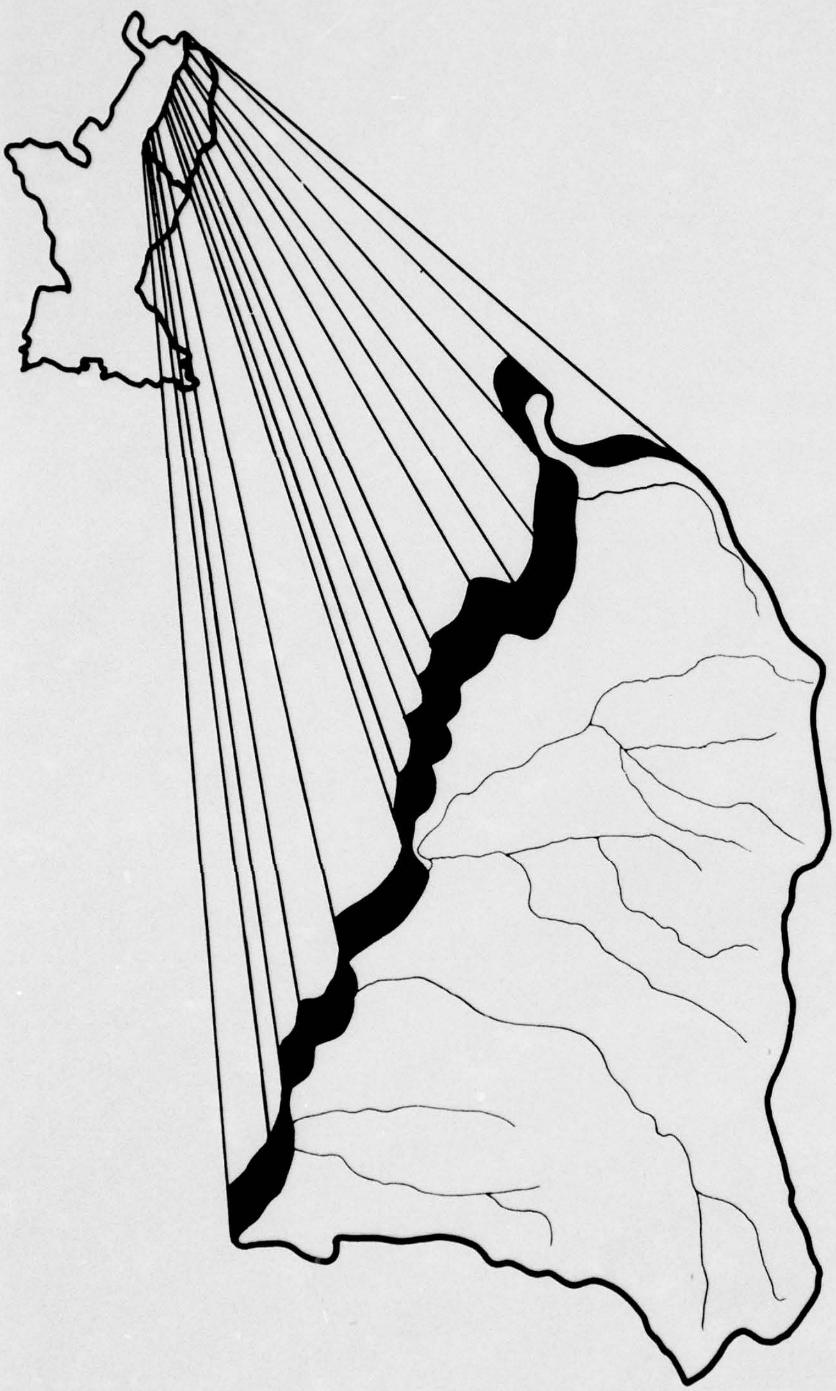
Most of the major aquifers in WRPA 2 have experienced some decline in regional water levels. The aquifers affected are (1) the Mississippi River Valley alluvial aquifer in the Grand Prairie Region, (2) the Memphis aquifer in the Memphis-West Memphis area, (3) the Sparta Sand in the southwestern part of the area, and (4) the lower Wilcox aquifer in the Memphis-West Memphis area.

In the Grand Prairie Region, the upper part of the Quaternary alluvium is sufficiently impermeable that recharge from precipitation does not replenish annual withdrawals for rice irrigation. The withdrawals have produced a widespread depression in the potentiometric surface of the aquifer; however, stabilization appears to be approaching as water level declines have essentially ceased in the central part of the cone and are proceeding at a steadily decreasing rate around the periphery. The aquifer should be able to supply irrigation demands, at least at the present withdrawal rate.

A large cone of depression in the Memphis aquifer has developed as a result of withdrawals for municipal and industrial use in the Memphis, Tenn., area. Although the lowering is not serious, the water levels are now about 100 feet below the original level at the center of the affected area, and the effect is measurable in adjacent parts of Arkansas and Mississippi. A similar cone of depression has developed in the lower Wilcox aquifer.

Withdrawals from the Sparta Sand have resulted in a regional lowering of water levels in the aquifer averaging about 70 feet. The largest declines have occurred in the southwestern part of WRPA 2 as a result of pumping at Pine Bluff (in WRPA 5).

Other management considerations include planned areal distribution of ground water withdrawals to achieve optimum yield; continued studies of the potential for artificial recharge; reservation of good quality ground water for highest priority uses; better delineation of shallow and intermediate saline water bodies; better delineation of the downdip extent of fresh water; and the utilization of saline water.



W R P A 3

W R P A 3

INTRODUCTION

WRPA 3 occupies a small area of Illinois around Cairo, Ill.; a portion of West Kentucky containing the Mayfield Creek, Obion Creek, and Bayou du Chien Basins; a portion of Tennessee west of the Tennessee River Divide; and the extreme northwestern portion of Mississippi containing part of the Hatchie River, Nonconnah and Horn Lake Creek Basins. The area covers 10,653 square miles, or about 10 percent of the total area of the Lower Mississippi Region.

The area is bounded on the north by the Ohio River Valley Divide, on the east by the Tennessee River Valley Divide, on the south by the Vicksburg District-Memphis District boundary, and on the west by the Mississippi River. The area is about 150 miles long with a maximum width of about 90 miles.

The most distinct physiographic feature of WRPA 3 are the Loess Hills which follow the Mississippi River for the length of the area. The Loess Hills are the result of an epoch of aggradation by wind. These hills are distinguished by the almost vertical bluffs left by erosion, and they overlie the steep slopes along the eastern side of the Mississippi Alluvial Plain. The Loess Hills rise to about 500 feet above sea level at the north end and decline in elevation toward the south. Crustal movement has played an important role in creating the existing landforms in the northern end of the WRPA. The most conspicious remnant of earthquakes is Reelfoot Lake, which lies directly over a major fault in the basement rocks in the northwest corner of Tennessee.

Streams originating within this WRPA averaged about 19 inches of runoff per year, or 13,800 cubic feet per second (c.f.s.) during the period of record.

The WRPA is drained by four major river systems and by numerous lesser creeks. The major rivers are the Obion, Hatchie, Loosahatchie, and Wolf Rivers. Of the four, the stream gradients for the Obion system are the steepest, ranging from about 3.3 feet per mile in the upper reaches to about 0.4 foot per mile near the Mississippi River. The Obion Basin contributes about 21 inches of runoff per year in WRPA 3.

The stream gradient for the Hatchie ranges from about 2.4 feet per mile in the upper reaches in Mississippi to about 0.9 foot per mile in the lower portion in Tennessee. The basin contributes about 18 inches of runoff per year in WRPA 3.

The Loosahatchie has a gradient of about 2.0 feet per mile. The basin contributes about 19 inches of runoff per year in WRPA 3.

The stream gradient for the Wolf is about 2.8 feet per mile. The basin contributes about 18 inches of runoff per year in WRPA 3.

The lesser systems in the area are drained by Mayfield Creek, Obion Creek, Bayou du Chien, Reelfoot Bayou, and Nonconnah Creek.

Soils along the streambeds and banks consist of Pleistocene loams, loess, gravels, and sand. Most of the area is covered by a thin deposit of loam varying in thickness to a maximum of about 12 feet.

The largest cities in the area, with their 1970 populations, are: Memphis, Tenn. - 623,530; Jackson, Tenn. - 39,996; and Dyersburg, Tenn. - 14,523.

SURFACE WATER

The majority of the streamflow which originates within WRPA 3 is produced by the Obion and Hatchie River Basins. At the present time, there is no regulation by major dams on streams in this area. There are, however, numerous headwater retention structures on the lesser streams.

Quantity

The annual mean discharge of streams originating in WRPA 3 is 13,810 c.f.s. (10.0 million acre-feet annually). This averages 1.3 c.f.s. per square mile. This is a high yield when compared to that for the rest of the region. There is no additional discharge contributed to the area from the outside.

Present Utilization

Surface water withdrawals from streams in WRPA 3 during 1970 averaged about 850 c.f.s., and were equivalent to about 6 percent of the mean annual flow generated within the area. Surface water withdrawals constituted about 67 percent of the total water withdrawn in the area, with the remainder coming from ground water sources. Major surface water withdrawals were for thermoelectric power production (670 c.f.s.) and for fish and wildlife mitigation (135 c.f.s.).

Withdrawals from ground water sources in WRPA 3 during 1970 averaged about 420 c.f.s. The major uses of these withdrawals were for municipal water supply (210 c.f.s.) and for industrial purposes (145 c.f.s). All of the water withdrawn for municipal use in the area was taken from ground water sources.

About 215 c.f.s., or 17 percent of the total ground and surface water withdrawals from WRPA 3 during 1970, were consumed. The remaining 1,055 c.f.s. that was withdrawn was released and returned to streams. A net decrease in streamflow of 205 c.f.s. resulted from this return flow. Major consumption of water was for municipal water supply, which used an average of 78 c.f.s. Major nonconsumptive uses of water in the area were for fishing, boating, and other water sports.

Additional information on the withdrawals of ground and surface water in WRPA 3 during 1970 is given in table 15 of the Regional Summary. Also presented in this table are pertinent data on the consumption of water in this WRPA and in each of the other areas in the Lower Mississippi Region.

Stream Management

Competition for water among the various users necessitates efficient

stream management. The WRPA 3 stream management practices include changes in stream systems by the development of levees, channel improvements, and diversion of water for various uses. Some of these practices may not cause marked changes in streamflow, and many subsequent years of streamflow records may be required to define their effects on the stream system.

Impoundments. Table 67 gives pertinent data on the only reservoir in WRPA 3 which has a total capacity of 5,000 acre-feet or more. This reservoir is now under construction and will control a drainage area of about 16.2 square miles in the upper part of the Middle Fork of the Obion River watershed.

Table 67 - Reservoir Having a Total Capacity of 5,000 Acre-Feet or More, WRPA 3

Name	Stream	Total Storage (acre-feet)	Surface Area (acres)	Purpose
S.C.S. Site No. 5	Middle Fork Obion River	5,900	545	Flood control

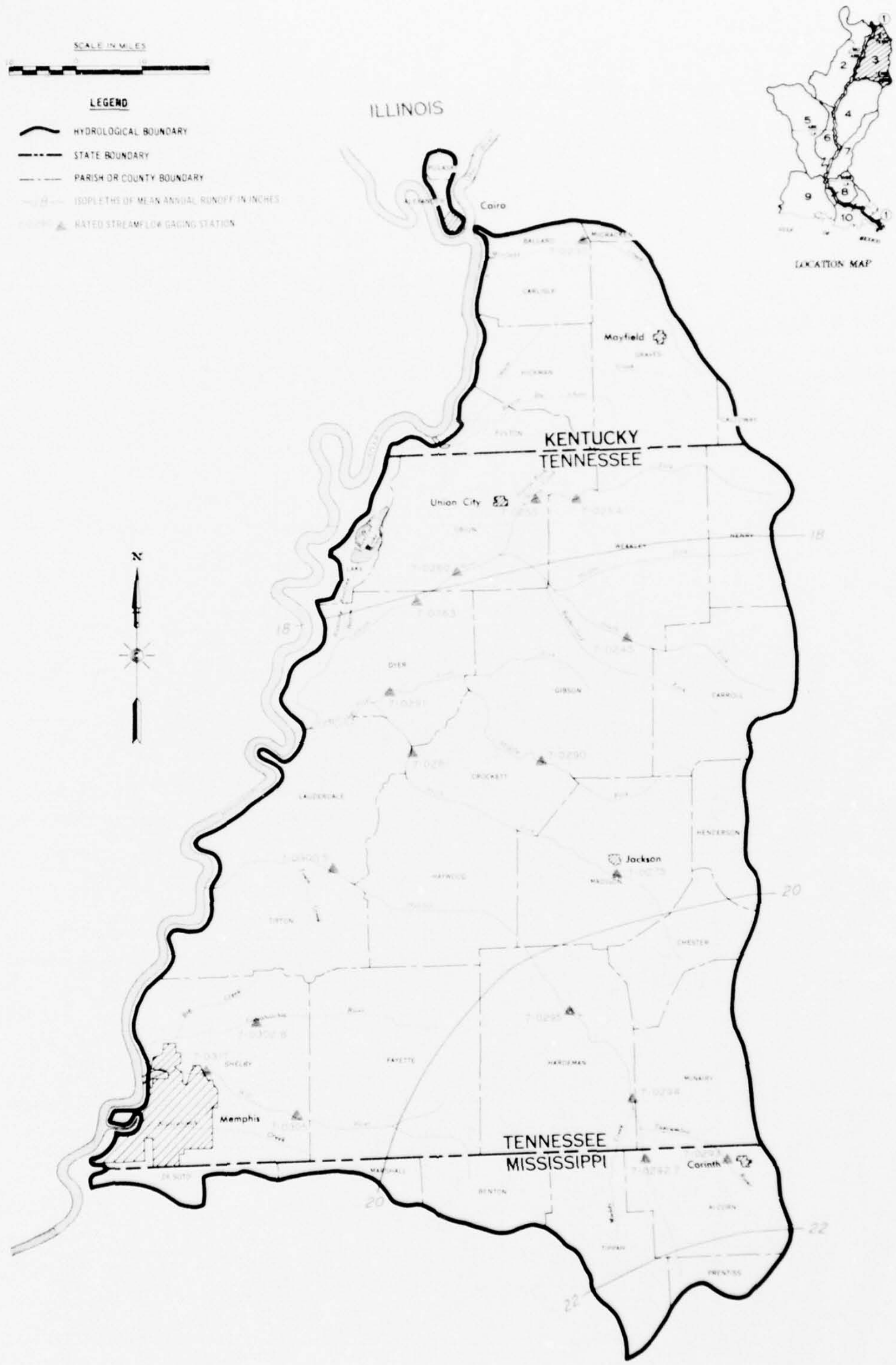
Channel modification. Throughout WRPA 3, channel modification has taken place on many of the streams. Flood-protection projects have been built on many of the streams in the area. These projects include levees, drainage structures, and channel clearing and construction. There are no navigation projects on any of the streams in WRPA 3.

Streamflow

The base period of streamflow data for WRPA 3 varies depending upon the period of record available at each gage site. For each of the selected gaging stations, the period of record provides reasonably good data for statistical analysis and study, and the data are considered representative of flows which could occur under 1973 levels of development.

Measurement facilities. Streamflow data at 12 sites were selected for detailed study in WRPA 3. Locations of these sites are shown in figure 130, a map of the mean annual runoff for the area, and are identified by the U. S. Geological Survey station numbers. Table 68 is a summary of the streamflow data at each of the selected sites and presents pertinent data for each site.

Average discharge for WRPA 3. A graphical representation of the average monthly discharge generated within WRPA 3 is shown in figure 131.



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

MEAN ANNUAL RUNOFF IN INCHES

WRPA 3

FIGURE 130

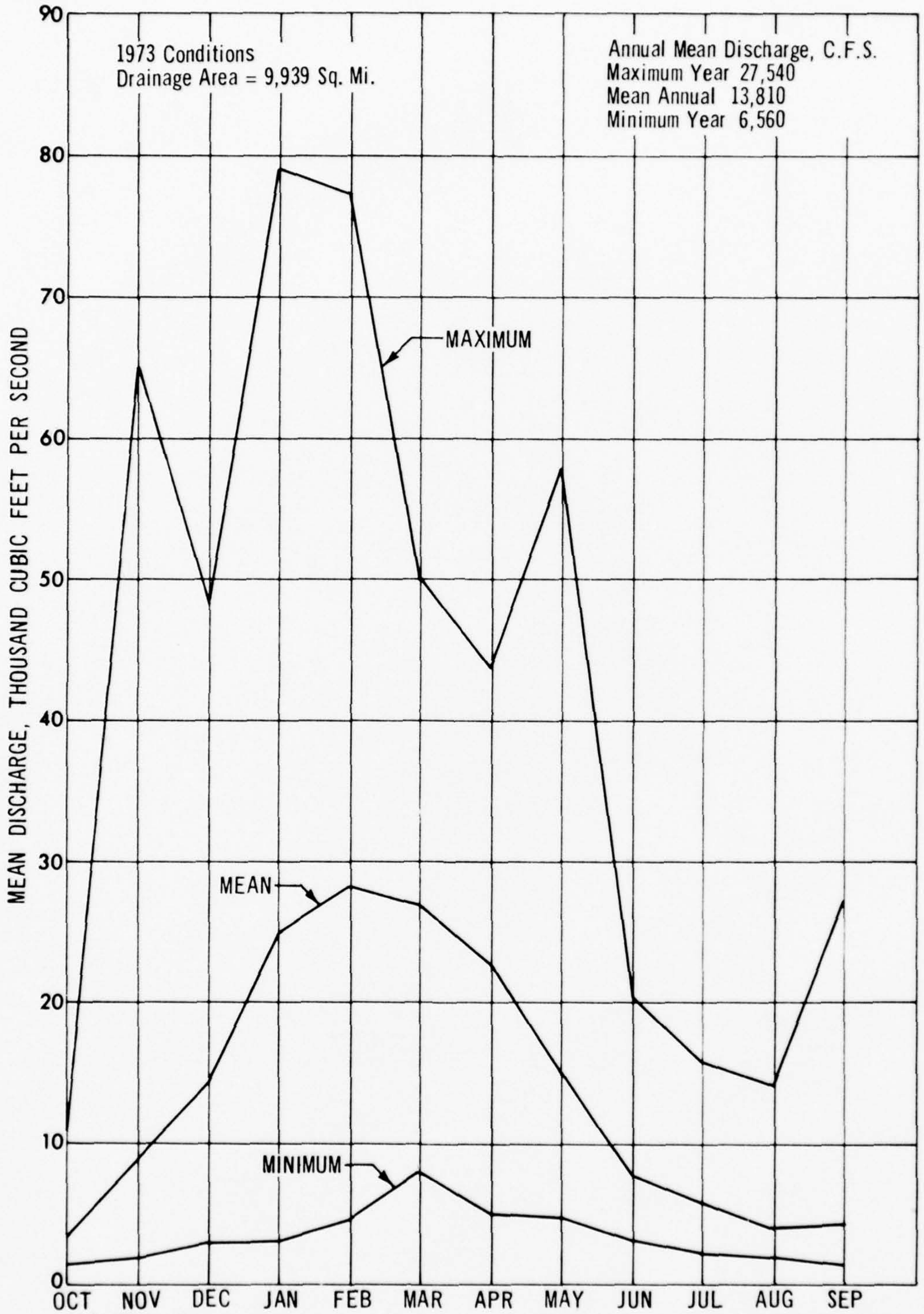


FIGURE 131

MONTHLY DISCHARGE FROM WRPA 3

Table 68 - Streamflow Summary for Selected Sites, WRPA 3

Stream	Station	Station No.	Gage Datum	Drainage Area (square mile)	Period of Record	Mean Annual Flow 1/ (c.f.s.) Mean	Mean Annual Flow 1/ (c.f.s.) Maxi-mum	Mean Annual Flow 1/ (c.f.s.) Mini-mum	Momentary Flow 2/ (c.f.s.) Maximum	Momentary Flow 2/ (c.f.s.) Mini-mum
Mayfield Creek	Lovelaceville, Ky.	0230	326.22	212	38-69	234	554	31	16,100	6
South Fork Obion River	Greenfield, Tenn.	0245	300.36	383	29-69	546	1,184	136	25,600	61
North Fork Obion River	Union City, Tenn.	0255	286.88	480	29-69	611	1,385	174	49,200	82
Obion River	Obion, Tenn.	0260	261.48	1,851	29-69	2,420	5,023	569	99,500	230
South Fork Forked Deer Creek	Jackson, Tenn.	0275	330.76	495	29-69	694	1,286	192	43,600	67
South Fork Forked Deer Creek	Halls, Tenn.	0281	259.09	1,014	47-69	1,330	2,554	631	26,900	94
North Fork Forked Deer River	Dyersburg, Tenn.	0291	244.86	939	47-69	1,327	2,918	474	22,400	85
Hatchie River	Bolivar, Tenn.	0295	323.49	1,480	29-69	2,282	3,910	969	56,300	78
Hatchie River	Rialto, Tenn.	0300.5	239.81	2,308	39-69	3,150	6,089	960	55,700	180
Loosahatchie River	Brunswick, Tenn.	0302.8	227.25	506	39-69	710	1,533	141	39,700	46
Wolf River	Rossville, Tenn.	0305	300.74	503	29-69	657	1,179	277	40,000	100
Wolf River	Raleigh, Tenn.	0317	217.22	770	36-69	1,040	2,143	395	41,400 3/	0 4/

1/ Regulated values for period of record.
2/ Observed values for period of record.
3/ Discharge not determined for record high gage.
4/ Affected by Mississippi River backwater.

Figure 131 presents the maximum, mean, and minimum monthly flows for the area. All of the flows originate from within the WRPA with no flows entering the area from the outside.

Average discharge for selected stations. Detailed data for each of the sites listed in table 68 are presented in tables 69-80, which are self-explanatory. The tabulated flows reflect regulation and use for a period of record that is representative of 1973 levels of development in the area.

Figures 132-143 present peak flow frequency curves for selected sites in WRPA 3. These curves are a reflection of the annual peak discharges for the station and were computed using the standard method of the Corps of Engineers [6].

Low flow frequency curves for selected sites are shown in figures 144-155. These curves represent the lowest average flows for periods of 3, 7, 14, 30, and 120 consecutive days.

Duration curves for daily flows at selected sites in WRPA 3 are presented in figures 156-167. These curves indicate the percent of time that any given flow at the site is equaled or exceeded.

Tables 81-92 present data on the dependable yield characteristics

at each of the selected discharge sites. These tables show the lowest mean flows for from one to ten consecutive years of the period of record. The relationship of these lowest mean flows to the period of record mean flow is also shown. The minimum yearly flow for the stations in WRPA 3 ranges between 13 and 47 percent and averages 31 percent of the mean annual flow.

For the ten consecutive years of lowest mean flow, the dependable yield averages about 80 percent of the mean annual flows for the WRPA.

Flow Velocities

No flow velocities for streams in WRPA 3 were available for publication in this report due to a lack of travel time studies in the area.

River Profiles

Representative river profiles are presented in figures 168-171. The profiles were prepared using topographic maps and data from available reports.

Quality

The quality of surface waters in WRPA 3 is such that generally they would be excellent sources for municipal and industrial water supplies. The dissolved-solids content in samples collected at 19 sites ranged from 13 to 248 mg/l, and most samples contained less than 50 mg/l of dissolved solids (table 93). Water from streams draining most of the unconsolidated deposits is soft (0-60 mg/l hardness as $CaCO_3$). The water has a low dissolved-solids content and only small variations in the chemical characteristics. For most uses, it would be desirable to treat for color, for iron removal, and for pH control. The dissolved-solids content of water from streams draining terrace deposits is the highest in the area but is not excessive. Water from these deposits is very hard (more than 180 mg/l hardness) and for many uses softening would be desirable. The principal constituents of water in the streams draining terrace deposits are calcium, magnesium, and bicarbonate [108].

Table 69 - Observed Mean Discharge, in c.f.s., Mayfield Creek at Lovelaceville, Ky., Sta 7-0230

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1939	13	26	14	348	1254	483	810	29	42	27	11	14	248
1940	17	12	15	100	552	481	603	185	135	37	14	10	178
1941	9	42	55	85	27	13	20	14	16	64	19	11	31
1942	42	25	29	415	546	492	513	60	16	16	179	12	193
1943	19	76	211	34	50	763	67	440	67	16	34	23	152
1944	9	11	11	11	214	411	506	219	36	15	18	15	122
1945	11	23	63	216	757	1004	1020	477	669	17	29	53	357
1946	82	116	152	725	1063	179	33	492	28	22	102	12	246
1947	23	335	399	623	44	80	484	258	160	17	21	20	206
1948	68	75	115	185	542	963	266	43	25	43	15	37	197
1949	15	391	922	1211	1080	763	174	27	72	184	29	32	406
1950	307	28	569	1952	1413	655	250	284	426	185	274	351	554
1951	25	396	244	1291	735	453	320	28	213	70	26	44	318
1952	16	368	1018	843	459	989	260	77	19	21	30	30	345
1953	15	21	129	195	216	1050	157	585	27	22	20	10	205
1954	11	19	38	168	145	123	161	207	91	23	18	100	92
1955	73	18	227	37	390	642	560	201	157	111	50	44	208
1956	22	30	24	217	834	225	173	94	22	38	28	16	141
1957	13	24	26	486	552	104	511	800	481	145	95	21	269
1958	46	1706	938	393	113	856	211	372	34	66	38	43	403
1959	18	30	22	258	460	91	50	42	62	103	82	85	106
1960	63	42	286	292	221	389	242	299	132	51	23	30	173
1961	19	41	80	105	872	756	701	775	111	58	23	19	293
1962	17	118	281	702	1050	771	380	68	43	25	35	227	305
1963	70	21	38	27	34	611	57	92	22	18	137	20	97
1964	19	22	19	17	24	1864	177	28	20	17	17	91	195
1965	35	25	245	456	497	882	494	39	51	167	18	113	250
1966	19	38	22	949	572	56	754	546	40	42	27	27	256
1967	25	29	299	88	138	490	51	697	77	235	223	39	201
1968	61	66	570	194	382	662	684	291	47	140	31	29	263
Mean	39	139	235	421	508	577	356	259	111	67	56	53	234

Table 70 - Observed Mean Discharge, in c.f.s., South Fork Obion River near Greenfield, Tenn., Sta 7-0245

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1930	218	424	383	2090	1000	755	309	1010	150	117	109	129	558
1931	125	163	194	203	682	715	368	178	137	198	265	131	278
1932	110	230	1060	3760	1460	679	1040	342	137	255	270	390	812
1933	198	239	605	1520	1300	1070	1360	937	127	342	288	180	678
1934	132	149	939	280	365	1210	238	170	191	132	127	323	356
1935	162	443	221	2850	495	1240	1070	595	694	168	111	112	682
1936	126	175	164	262	254	1350	227	121	100	243	98	129	272
1937	127	208	343	5850	370	366	405	552	515	149	131	295	784
1938	411	268	528	1150	1110	859	387	297	821	268	379	118	546
1939	102	121	137	718	2400	1100	1170	615	709	173	129	99	609
1940	103	118	159	153	580	889	681	380	166	189	147	93	304
1941	95	138	162	170	147	132	187	120	101	148	151	86	136
1942	111	163	188	599	967	955	1210	162	172	141	117	86	402
1943	102	143	520	274	199	1900	465	949	154	91	107	119	422
1944	85	154	145	184	938	1120	1370	406	128	119	186	247	420
1945	232	275	861	1650	1000	1210	805	885	1410	125	150	139	727
1946	289	1220	506	1940	1230	1310	387	391	140	454	167	122	677
1947	148	445	688	1880	304	400	884	877	205	201	163	123	530
1948	282	507	332	434	1450	1300	586	265	128	345	182	169	495
1949	129	1640	1110	1920	976	1300	660	264	771	426	347	174	808
1950	507	278	2114	2910	2680	1340	492	1130	347	594	540	1310	1184
1951	288	953	1100	2630	1870	740	1110	191	316	624	214	264	852
1952	166	1280	2420	1070	1170	1600	620	255	165	140	141	190	768
1953	149	194	297	384	751	2060	815	2200	176	152	107	103	618
1954	111	139	204	1530	604	475	455	380	255	99	99	91	370
1955	98	108	219	161	764	1820	1110	505	217	189	160	112	453
1956	147	235	166	926	3610	803	964	321	154	105	100	84	621
1957	90	129	149	862	1600	528	895	941	573	726	216	169	566
1958	182	2920	1370	539	446	1080	761	1030	197	704	158	165	797
1959	122	239	299	841	1220	447	276	212	295	321	219	251	389
1960	212	225	713	561	516	816	434	455	133	182	153	116	377
1961	104	225	276	318	893	1380	899	561	616	202	132	109	473
1962	134	376	2210	1060	1660	1850	1430	476	205	146	108	256	822
1963	175	155	172	157	203	1340	195	267	160	153	158	137	274
1964	97	125	144	362	349	1850	1010	468	122	285	930	139	493
1965	153	242	1590	851	1840	1130	1020	182	213	184	97	117	628
1966	97	150	135	312	966	266	254	956	122	108	99	100	293
1967	125	170	436	336	272	804	156	2020	134	481	233	106	445
1968	194	178	737	632	494	1563	1577	494	197	124	97	112	534
1969	132	219	561	539	960	369	1423	172	167	108	191	101	407
Mean	164	394	614	1122	1002	1053	730	568	293	248	194	182	546

Table 71 - Observed Mean Discharge, in c.f.s., North Fork Obion River near Union City, Tenn., Sta 7-0255

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1930	149	446	653	3500	990	553	466	459	162	138	130	131	649
1931	110	121	169	166	198	309	310	175	282	143	187	156	194
1932	108	368	1250	3500	1380	1030	972	172	126	138	337	583	832
1933	351	203	936	2490	1060	1540	2510	1920	150	1450	423	453	1127
1934	280	206	1170	266	602	1310	253	262	249	132	186	611	461
1935	379	1440	673	2970	463	2690	1540	690	681	171	186	117	1005
1936	153	181	221	267	308	348	321	123	107	152	101	186	205
1937	106	273	450	6740	469	291	426	919	671	110	113	115	899
1938	251	162	471	714	1300	796	298	393	270	336	339	126	451
1939	123	160	147	902	2120	1130	1310	376	665	168	116	102	598
1940	121	124	160	356	1170	953	1230	407	327	192	194	102	441
1941	100	153	209	220	144	235	184	125	113	356	151	91	174
1942	146	145	152	694	1180	1360	1250	182	127	109	699	110	509
1943	135	240	644	167	242	2020	199	312	225	98	99	118	378
1944	89	117	115	125	820	1180	1370	1060	142	119	129	139	449
1945	91	162	322	779	1290	1820	1460	1090	1840	133	215	195	777
1946	319	521	309	1600	2280	1020	268	735	138	178	155	112	627
1947	141	373	548	1300	188	238	816	872	205	144	120	153	428
1948	228	336	285	308	1300	1700	636	164	125	250	115	186	467
1949	127	1640	2070	1920	1960	1420	797	176	397	659	487	217	983
1950	1160	256	1530	4000	2760	1240	779	968	499	1310	891	1260	1385
1951	241	1240	849	2840	2120	1060	976	216	587	543	169	309	921
1952	168	846	2070	996	1010	3250	594	226	174	208	171	217	830
1953	142	183	360	544	713	2260	550	1730	204	141	112	106	590
1954	110	137	260	708	555	826	507	304	519	140	114	117	357
1955	196	119	333	188	892	1700	1000	545	321	349	178	160	496
1956	190	217	182	573	1378	698	758	255	164	253	115	102	593
1957	101	151	150	1070	1440	327	1180	1680	1430	498	324	133	702
1958	213	4480	2160	688	350	1480	616	941	183	521	200	201	1004
1959	132	214	186	765	1150	357	296	310	386	354	312	306	392
1960	424	330	774	787	412	674	318	584	382	267	142	135	438
1961	123	236	267	243	1930	1830	1200	749	582	250	124	119	628
1962	148	412	1100	1370	2000	2330	1380	473	211	174	148	337	834
1963	160	156	173	162	185	947	218	320	210	165	275	124	259
1964	109	142	147	178	236	3720	590	196	142	138	186	383	517
1965	161	182	936	1100	1390	1640	1220	194	178	695	117	252	668
1966	126	257	167	1390	1350	241	1160	1250	145	150	156	148	540
1967	146	178	806	348	317	1230	240	1980	219	649	364	152	558
1968	220	244	1047	505	773	1135	1579	526	196	223	132	134	559
1969	143	266	421	1230	978	415	1947	194	237	184	279	158	533
Mean	198	440	622	1217	1035	1233	843	606	349	310	225	221	611

Table 72 - Observed Mean Discharge, in c.f.s., Obion River at Obion, Tenn., Sta 7-0260

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1930	525	1540	1600	13300	4520	3300	1430	3450	529	533	355	397	2622
1931	419	525	625	597	1140	1300	1410	567	498	584	740	532	742
1932	396	879	4690	14900	8960	2440	5370	1080	505	673	1010	1570	3528
1933	1340	826	1710	9680	4480	4640	11200	5170	523	2340	1990	1190	3752
1934	899	736	4890	1260	1060	7150	1560	758	680	487	635	942	1769
1935	1080	4210	1870	10700	2220	7490	6110	2410	3360	755	562	431	3444
1936	479	610	636	935	1040	1960	1690	487	323	713	277	457	800
1937	430	923	1420	26600	2020	1280	1300	3290	2860	626	492	765	3538
1938	1750	726	1360	3520	5590	3080	2130	1310	2730	884	2310	502	2136
1939	350	441	505	2430	12400	4670	7340	2040	4400	983	540	344	2960
1940	378	452	630	894	3570	3380	4150	1450	785	832	632	339	1446
1941	315	528	754	790	543	628	678	500	337	927	465	349	569
1942	459	609	620	1730	4500	4690	4730	541	568	436	1050	306	1665
1943	325	793	1060	1500	772	7320	1620	2280	1530	310	517	489	1554
1944	249	490	495	587	2740	5690	5900	3230	545	301	481	520	1762
1945	613	718	1230	5860	3440	5310	5610	3720	8280	421	561	577	3017
1946	1230	3370	1540	7250	6640	3860	1960	1760	705	1510	644	400	2548
1947	514	1520	2020	6620	1110	1200	3090	2830	1250	526	421	421	1803
1948	665	2240	1240	1550	6370	7170	3080	668	377	793	553	717	2103
1949	408	5950	5640	8010	6830	4720	3280	904	2430	2270	1350	608	3511
1950	2910	945	6420	13300	12400	5040	3200	4010	1830	3630	2050	5040	5023
1951	932	4250	3890	11600	7370	3620	4050	813	2100	3280	677	985	3608
1952	545	3920	11100	5430	5530	10600	2820	770	508	675	494	613	3590
1953	407	700	1280	1500	2350	9210	2500	9080	603	503	364	352	2419
1954	355	474	804	3840	2520	2220	1670	1570	1310	367	371	348	1315
1955	437	372	760	837	2820	6980	4270	1580	1270	1050	522	319	1762
1956	603	651	924	788	16600	3020	3010	1200	515	664	357	264	2320
1957	270	437	520	2520	8850	2070	4910	6660	5240	3970	1100	512	3044
1958	742	15500	8760	3090	2100	5940	3120	4820	669	1980	589	708	4006
1959	657	1634	2371	4815	4470	4759	3732	2584	1474	1131	744	714	2420
1960	657	1634	2371	2160	1600	2930	1210	2100	793	1020	496	477	1450
1961	395	890	1130	1180	4690	7200	3570	3550	2590	882	573	533	2265
1962	415	1580	5830	4420	5120	11480	6890	3070	811	600	411	1300	3494
1963	773	561	582	580	699	4931	650	1201	900	524	505	648	1046
1964	323	395	434	891	1140	10500	3730	1800	577	597	896	935	1852
1965	991	934	4900	4620	6000	5530	5880	779	1210	2090	392	914	2853
1966	460	774	663	3810	4920	961	2250	5230	600	717	645	430	1788
1967	443	607	2240	1440	1070	4540	806	11000	803	3240	1420	559	2375
1968	814	701	3590	2450	2930	5750	8460	2420	884	836	485	545	2489
1969	513	1090	2270	4620	5660	1800	8920	692	1040	580	1100	492	2398
Mean	657	1634	2371	4815	4470	4759	3732	2584	1474	1131	744	714	2420

Table 73 - Observed Mean Discharge, in c.f.s., South Fork of Forked Deer River at Jackson, Tenn., Sta 7-0275

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1930	471	785	488	2570	1690	1470	553	1180	167	188	208	199	828
1931	244	267	408	357	1140	1020	559	233	132	525	903	138	491
1932	107	331	1890	3710	1920	798	1060	525	200	1210	379	655	1065
1933	341	419	958	1270	2250	1560	2220	1570	170	354	290	516	984
1934	159	243	1920	491	374	2050	396	315	692	208	215	481	633
1935	214	755	482	3300	813	1740	1260	692	1200	259	140	177	921
1936	261	275	206	543	453	994	352	198	88	852	95	231	380
1937	206	359	455	4740	600	465	493	926	418	507	206	189	803
1938	339	290	566	1790	820	1110	748	397	675	288	319	153	624
1939	109	246	215	1200	3540	1050	1630	785	1990	299	444	113	947
1940	125	171	248	212	1110	1100	667	375	185	314	221	103	400
1941	107	213	389	318	219	244	213	127	94	154	144	80	192
1942	137	289	279	498	715	1420	1610	175	169	112	192	112	473
1943	140	241	881	377	350	1570	430	527	188	145	254	441	465
1944	97	326	320	438	2390	1330	2410	529	213	124	178	225	705
1945	246	357	1260	1760	1490	1770	1120	1050	1030	190	296	330	907
1946	440	1950	1080	3770	1770	1800	564	452	221	728	432	288	1123
1947	249	751	879	2500	509	734	1200	1050	395	177	299	298	757
1948	467	826	504	949	3350	1620	1400	304	182	270	132	230	841
1949	198	2030	1660	2600	977	1400	942	674	1770	352	419	236	1105
1950	453	368	1680	3850	3260	1860	639	821	629	365	639	990	1286
1951	285	922	1110	2480	1980	1170	1740	289	375	458	232	218	930
1952	217	1240	2630	1540	1330	2170	744	313	181	153	223	366	927
1953	169	322	366	559	1640	1550	917	2380	195	210	123	107	708
1954	116	168	304	2440	1100	459	508	384	169	141	96	93	496
1955	112	126	221	212	848	2030	1530	777	272	583	186	179	588
1956	195	267	242	612	3360	854	1430	368	278	124	138	89	650
1957	97	132	304	1760	1900	739	1430	1130	663	515	185	538	775
1958	299	2360	1310	611	427	1010	1010	836	187	599	150	577	782
1959	166	324	236	959	1610	567	460	177	394	296	238	162	458
1960	217	300	918	683	714	1030	456	472	162	238	169	161	461
1961	156	243	337	345	1120	1470	899	375	363	166	155	121	475
1962	119	377	1320	2430	1710	1570	1110	786	301	156	115	245	850
1963	173	175	204	213	354	1430	276	637	216	182	126	102	342
1964	97	149	210	334	440	1140	1950	396	179	521	337	352	508
1965	214	354	2030	1100	1940	1710	1700	316	535	214	127	140	858
1966	145	179	197	298	1100	453	403	1200	192	154	139	152	381
1967	133	172	475	371	340	920	250	1660	187	393	251	159	446
1968	246	217	1395	1018	386	1255	1428	1153	153	119	98	156	638
1969	212	700	1005	492	1267	470	1837	271	188	115	222	171	572
Mean	212	505	790	1393	1333	1227	1014	671	400	324	243	257	694

Table 74 - Observed Mean Discharge, in c.f.s., South Fork of Forked Deer River near Halls, Tenn., Sta 7-0281

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1947	400	1750	1140	6130	1080	1550	1750	1560	829	305	414	374	1440
1948	443	1770	856	1390	4980	3440	2540	468	366	433	298	419	1450
1949	271	2840	3030	4450	2130	1970	1930	1080	3020	658	584	385	1862
1950	758	568	3350	6690	7550	3240	929	1790	934	979	1550	2310	2554
1951	427	1880	2090	5990	3860	1730	3090	710	669	930	353	474	1850
1952	286	1900	4300	2300	3290	3760	1630	482	326	262	461	549	1629
1953	222	415	599	834	2830	4080	1730	5740	378	387	192	174	1465
1954	191	263	502	4270	1990	1030	851	1060	360	221	174	172	924
1955	195	200	353	336	1460	4300	3320	844	1190	1160	312	211	1157
1956	421	421	444	952	8360	1550	2590	836	402	284	205	147	1384
1957	147	206	348	1450	5760	1190	2470	1610	2040	1300	658	650	1486
1958	596	5650	3310	1150	864	2130	2000	2370	319	790	265	669	1676
1959	329	534	415	1380	3110	1100	706	376	641	675	466	442	848
1960	353	384	1050	952	998	1690	685	935	331	668	272	284	717
1961	278	418	557	615	1620	2920	2150	916	625	390	286	251	919
1962	235	752	3180	3740	3090	4660	2460	1120	391	239	182	607	1721
1963	294	313	303	327	469	2850	421	906	910	336	240	197	631
1964	167	234	306	469	615	3340	3660	1460	323	917	963	299	1063
1965	452	587	4190	2050	4640	2670	4430	492	732	635	305	564	1812
1966	252	394	318	670	2570	761	561	2640	358	365	287	239	785
1967	245	275	688	893	615	1790	473	2760	450	937	376	265	814
1968	362	309	1980	2100	1140	2760	3830	2260	341	230	178	240	1311
1969	291	409	2280	1660	2540	772	3460	476	279	196	502	239	1092
Mean	326	953	1521	2209	2850	2404	2072	1430	705	578	414	442	1330

Table 75 - Observed Mean Discharge, in c.f.s., North Fork of Forked Deer River at Dyersburg, Tenn., Sta 7-0291

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1947				4680	740	955	1920	1240	565	295	333	189	
1948	395	1480	731	846	3610	3160	1410	255	160	275	168	233	1060
1949	171	3240	2640	4310	2830	2660	1920	723	3220	710	389	299	1926
1950	964	446	3630	7220	6820	3340	1620	2500	1000	2020	1680	3770	2918
1951	387	2230	2050	6426	3811	1880	2434	527	723	1802	417	459	1929
1952	245	1849	4044	2360	2910	3900	1660	332	220	307	411	478	1560
1953	166	275	572	653	1920	4550	1960	6350	400	323	124	137	1453
1954	144	235	425	3270	1720	865	620	992	1080	185	157	140	819
1955	153	156	333	265	1270	3780	3050	657	801	957	346	151	993
1956	388	375	531	578	9260	1610	1820	912	285	140	126	112	1345
1957	145	189	235	1080	5190	1080	2740	3190	2900	2340	555	269	1659
1958	431	6620	3620	1510	1120	2570	1890	3000	215	783	201	451	1868
1959	219	418	369	1300	3480	1140	553	318	519	736	517	414	832
1960	374	282	924	957	732	1780	546	1100	373	414	229	227	662
1961	184	414	536	529	1730	3380	2250	1710	1160	404	249	231	1065
1962	144	799	3650	2490	2820	5720	3430	1250	487	233	122	639	1815
1963	210	240	191	191	257	2544	369	537	550	250	181	162	474
1964	111	144	164	288	361	4300	3370	1420	415	492	869	373	1026
1965	317	549	3290	1940	4040	2730	3390	306	972	705	247	511	1583
1966	237	420	402	1400	2680	604	415	2570	438	571	458	172	864
1967	145	192	625	1250	645	1800	298	5450	402	1720	313	134	1081
1968	237	254	1510	1390	1440	2740	4780	1840	361	259	159	192	1264
1969	196	251	1540	1860	2650	668	3240	373	264	232	473	221	997
Mean	266	925	1412	2034	2697	2511	1986	1633	761	702	379	433	1327

Table 76 - Observed Mean Discharge, in c.f.s., Hatchie River at Bolivar, Tenn., Sta 7-0295

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1930	957	3840	1830	6260	3810	4350	926	2380	348	263	487	981	2203
1931	363	1020	1280	1550	1930	3610	2590	1060	368	949	2680	294	1475
1932	162	639	7120	12000	10000	2310	3300	1360	752	5930	846	2220	3887
1933	4450	2070	4580	4720	8580	5760	7510	5640	630	837	537	701	3835
1934	414	603	3070	1430	829	5050	1890	591	1460	968	526	460	1441
1935	508	2010	2050	9260	4540	5670	3420	1800	1360	652	315	380	2664
1936	1150	1980	741	1990	2300	3340	4200	642	283	568	278	757	1519
1937	1720	2030	2860	12800	2240	1540	1270	1640	529	552	313	540	2336
1938	683	703	1090	4190	3300	3340	5280	1110	2560	945	539	335	2006
1939	183	531	559	3630	8600	3880	5300	3090	6320	1480	541	231	2862
1940	283	381	682	697	2750	3140	3910	1240	525	797	458	298	1263
1941	180	985	2260	2230	1200	1050	1300	563	209	734	510	407	969
1942	482	1450	1490	1660	3180	3820	3870	444	490	265	384	310	1487
1943	182	530	1800	2430	2620	4720	1580	1210	334	189	227	823	1387
1944	171	777	653	1590	6100	6900	8010	2270	317	239	344	897	2356
1945	701	490	1670	8890	3980	6570	3000	2570	1550	334	451	502	2559
1946	1090	7090	4230	12500	7480	4890	3550	1530	1570	1580	841	574	3910
1947	513	2800	1450	6740	2360	3020	4040	2240	1760	673	371	507	2206
1948	533	2010	1480	3090	14100	6360	4810	1990	869	944	397	528	3092
1949	395	6240	4360	9180	5030	4510	5620	1660	2810	973	943	430	3513
1950	862	960	3310	10700	9550	6740	2480	2230	1710	854	1850	4490	3811
1951	661	3220	4100	7650	9320	4660	6000	1050	787	1370	388	340	3296
1952	366	1730	7810	4840	5640	6390	2880	1070	471	268	679	287	2703
1953	286	577	854	1510	8070	6610	4050	9490	509	2080	464	205	2892
1954	208	340	758	4450	4390	1710	1960	1480	612	287	193	131	1377
1955	192	243	422	555	2140	7640	6030	1270	936	2020	418	178	1837
1956	219	553	682	661	10600	2560	4350	1860	557	400	207	127	1898
1957	150	233	1150	2940	11000	2810	5480	1190	2320	1380	418	1300	2531
1958	797	7460	4790	2200	1760	2350	3570	5880	644	1210	453	2740	2821
1959	825	992	883	3290	3740	2120	2310	761	1860	482	294	347	1492
1960	1120	681	3760	3800	3540	5190	1650	1380	653	661	471	340	1937
1961	654	667	945	1790	3980	7720	3710	1010	469	485	352	258	1837
1962	261	1620	7350	7530	5560	6250	4370	1070	1200	507	243	555	3043
1963	393	439	477	561	1320	3830	1050	3200	2520	1010	396	279	1290
1964	167	340	724	1450	2080	4720	6840	1370	338	550	559	280	1618
1965	465	676	4690	4320	4140	4280	4300	880	552	348	230	298	2098
1966	297	368	462	742	4940	1550	7350	2950	355	407	414	296	1678
1967	406	520	1440	1830	1530	3820	1100	5160	453	1170	1390	399	1602
1968	535	557	5874	6483	1561	3703	4369	3127	540	270	218	289	2307
1969	483	839	4474	1609	5781	1689	9612	910	442	277	524	452	2222
Mean	589	1530	2505	4394	4889	4254	3971	2059	1074	898	554	644	2282

Table 77 - Observed Mean Discharge, in c.f.s., Hatchie River at Rialto Sta 7-0300.5

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1939				4870	15100	6730	8320	3860	9160	3460	875	480	
1940	420	495	635	905	3240	3940	3570	2710	690	1000	650	530	1565
1941	335	765	1455	2243	1381	1054	1118	975	394	723	511	564	960
1942	521	973	1478	2051	3659	7397	7941	927	661	430	590	369	2250
1943	294	662	1540	3979	2666	7717	3148	1245	799	262	327	706	1945
1944	310	521	639	1580	8092	6707	12546	4671	639	391	356	908	3113
1945	681	750	2729	14408	5580	11560	6820	4770	2784	697	791	823	4366
1946	1265	8783	8425	18800	11785	7900	6840	2100	2390	2870	1200	709	6089
1947	762	2480	3050	8810	3630	3610	4720	3250	2580	1240	574	674	2948
1948	643	3140	2060	3800	16600	10300	6730	2460	1240	1320	873	784	4163
1949	712	6530	7790	12400	6630	4820	7920	2420	3910	1840	1340	733	4754
1950	1110	1250	4520	15600	15800	7830	3420	3890	2590	1110	2220	7200	5545
1951	1020	3640	5660	11000	10800	5700	8500	2120	1220	1590	692	664	4384
1952	602	2170	7950	5870	8630	7930	4780	1670	989	560	956	665	3564
1953	469	797	1280	1580	8040	9040	5530	13300	1820	1560	1710	449	3798
1954	436	554	1130	6280	5700	3670	2250	2770	1010	510	409	363	2090
1955	441	461	633	896	2850	9260	10400	2740	2110	2370	1420	420	2833
1956	548	708	975	1530	14700	4750	4890	2660	947	873	442	320	2779
1957	332	435	1010	2410	13700	4510	7280	2780	4070	2170	1410	1440	3462
1958	1450	9190	8150	3450	3000	3640	4680	8380	962	1270	888	1570	3886
1959	2270	1350	1360	3420	7170	3650	2970	1410	2880	1230	728	654	2424
1960	1380	911	3680	4530	4730	6170	2880	2430	752	1060	711	545	2482
1961	899	973	1350	2580	3850	10000	7070	2210	1200	740	716	539	2677
1962	530	1660	8880	8890	7530	10250	5850	3030	1240	955	535	1230	4215
1963	659	674	707	787	1395	5269	1613	3149	3589	1277	703	568	1699
1964	394	508	841	1660	1970	7120	10500	4500	627	973	1160	555	2567
1965	918	909	6670	6420	7460	6320	15300	1350	1490	1100	518	727	4099
1966	508	563	703	1080	6140	3090	1210	4890	1310	711	746	545	1791
1967	629	721	1630	2340	1710	4790	1300	6280	983	1740	1710	756	2049
1968	654	737	4780	7750	3060	4760	7050	5040	1630	580	466	529	3086
1969	884	719	5260	3190	6690	2240	11100	2060	756	480	808	660	2904
Mean	732	1776	3202	5326	6880	6088	6072	3421	1852	1197	872	893	3150

Table 78 - Observed Mean Discharge, in c.f.s., Loosahatchie River at Brunswick, Tenn., Sta 7-0302.8

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1940	100	110	145	150	800	335	380	225	230	120	110	95	242
1941	70	100	175	231	113	167	287	142	73	146	123	64	141
1942	113	186	128	630	955	1340	1840	185	195	150	166	122	501
1943	182	189	1110	155	136	2370	463	280	175	102	83	317	464
1944	69	106	132	208	3260	1400	2890	804	114	95	64	332	790
1945	116	232	2820	2325	2580	2570	2042	937	864	119	116	225	1246
1946	212	2548	1440	4210	2710	2310	534	501	182	455	109	85	1275
1947	131	538	1170	3460	173	698	800	1420	1590	289	127	87	874
1948	161	649	405	600	4590	2860	1600	166	260	332	120	128	989
1949	94	2140	1630	3680	1030	2250	972	359	1310	180	325	129	1175
1950	409	177	1800	5750	5180	1800	313	1010	467	369	1360	755	1533
1951	204	1120	1650	5170	2370	737	939	137	581	537	115	133	1141
1952	126	498	1950	1580	1930	1990	698	172	118	118	114	97	783
1953	97	124	153	287	1650	2120	1000	3550	121	505	109	96	818
1954	104	142	311	2510	1470	170	358	709	189	123	160	109	530
1955	138	117	164	116	781	1900	1990	571	179	501	143	125	560
1956	137	128	112	471	3140	700	941	532	475	134	94	80	579
1957	83	95	112	2130	1620	709	1310	1250	768	280	216	422	750
1958	305	2410	1790	643	587	1090	1360	1170	144	234	118	476	860
1959	112	220	125	1110	1870	560	315	192	497	461	215	123	483
1960	119	108	411	491	544	1160	317	436	217	233	487	190	393
1961	166	202	409	349	1420	1380	1410	490	245	203	121	219	544
1962	101	447	1990	2193	1417	1381	805	956	238	149	108	1059	912
1963	121	140	109	117	190	1660	361	930	228	146	135	98	353
1964	85	98	113	200	307	1690	2650	350	133	312	273	164	531
1965	113	133	1580	1380	2045	1540	2434	179	267	151	140	365	860
1966	90	134	91	164	1590	300	419	1400	112	165	323	697	457
1967	102	103	955	224	248	495	374	569	169	924	136	101	367
1968	87	95	722	1110	597	1430	1860	1170	113	125	99	180	632
1969	324	321	1160	543	988	399	1790	140	123	121	348	119	531
Mean	142	454	829	1406	1516	1317	1115	698	346	259	205	237	710

Table 79 - Observed Mean Discharge, in c.f.s., Wolf River at Rossville, Tenn., Sta 7-0305

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1930	208	791	440	2080	827	956	237	938	177	176	152	368	613
1931	317	302	380	351	716	932	509	225	237	435	546	196	428
1932	132	459	2140	3280	2130	607	884	574	389	2250	443	857	1179
1933	390	380	1320	1060	2520	1680	1620	1200	260	301	407	719	978
1934	273	264	2250	519	321	1770	386	261	432	227	193	194	596
1935	194	951	411	3110	799	931	633	607	480	213	198	248	733
1936	449	351	231	460	386	563	376	190	160	243	146	358	326
1937	644	560	771	4400	483	582	283	314	303	183	155	176	745
1938	241	262	295	1270	765	1280	1580	291	969	364	204	163	638
1939	150	325	232	128-	2520	976	1450	882	1460	613	198	161	841
1940	163	197	252	245	563	399	574	402	291	223	218	151	305
1941	143	232	449	408	288	286	309	271	144	191	368	225	277
1942	320	519	324	499	975	879	1640	181	191	129	143	121	488
1943	135	193	747	297	535	1890	552	581	244	133	121	267	476
1944	141	247	250	349	2120	1650	2050	528	268	165	198	506	697
1945	281	315	997	1750	1840	1780	1020	482	345	281	270	356	804
1946	367	2450	1010	3180	1650	1970	569	595	339	459	225	199	1082
1947	229	531	407	1370	542	554	804	647	810	306	203	349	562
1948	251	770	476	959	3700	1500	1060	535	327	357	274	216	857
1949	226	2190	710	2240	783	1450	954	365	196	314	271	204	970
1950	288	246	1030	3000	2150	1650	423	400	494	252	608	572	921
1951	283	794	1300	2520	1820	995	987	315	301	535	246	236	856
1952	241	990	1910	1250	1380	1640	615	305	243	198	231	204	767
1953	189	310	357	403	1890	1250	964	3770	247	620	205	190	862
1954	199	232	389	1500	1660	368	380	525	339	168	175	150	450
1955	211	197	247	271	871	1850	2140	274	305	438	202	166	595
1956	158	279	296	450	2920	556	778	412	205	206	148	133	534
1957	142	181	343	1220	2150	574	989	461	871	300	260	469	651
1958	265	1750	1160	505	396	597	804	1520	270	315	220	975	732
1959	232	346	334	936	1060	750	477	257	558	193	224	224	461
1960	325	262	934	712	780	1170	350	434	364	181	299	181	500
1961	404	305	321	444	1610	1590	937	406	282	173	182	168	562
1962	195	563	185	1520	1500	1000	654	475	398	350	242	410	761
1963	250	270	285	281	456	1140	479	1070	529	213	172	165	444
1964	143	194	266	367	444	648	1920	404	158	234	257	272	440
1965	257	294	1940	1340	1600	1840	1110	339	259	198	184	199	793
1966	174	211	226	293	1530	469	336	1140	183	164	157	150	421
1967	178	237	407	381	362	1130	627	1450	270	1750	337	179	614
1968	185	218	973	1499	515	1243	1049	605	213	170	165	341	600
1969	541	1020	1227	520	1406	385	2079	270	225	188	336	230	694
Mean	252	530	747	1212	1274	1087	8894	623	413	360	247	291	657

Table 80 - Observed Mean Discharge, in c.f.s., Wolf River at Raleigh, Tenn., Sta 7-0317

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1936									256	419	226	583	
1937	703	875	1077	8191	660	866	459	461	566	284	252	241	1220
1938	360	398	459	1952	1800	1660	2782	458	1075	438	379	245	1001
1939	198	358	298	1845	5146	1569	2766	1160	1716	953	283	203	1375
1940	208	227	305	330	980	550	770	560	330	440	270	230	433
1941	180	300	590	610	410	400	550	430	220	270	410	340	395
1942	410	640	460	883	1479	2097	3035	320	322	238	269	204	863
1943	208	374	930	781	722	2884	935	925	494	225	193	382	754
1944	186	294	298	488	3108	2159	3556	1025	369	216	222	628	1046
1945	306	410	1664	3216	2071	3202	1813	813	570	311	333	379	1257
1946	490	3447	1778	6510	3110	2730	1400	889	550	714	292	226	1845
1947	265	788	916	2860	701	858	1160	893	1120	498	292	373	894
1948	338	1130	671	1170	6210	3110	1770	743	402	352	377	240	1376
1949	213	2350	1440	4540	1550	2930	2080	580	2870	523	424	319	1652
1950	577	433	1760	5430	4450	2830	901	1120	709	408	1170	1320	1759
1951	408	1350	2070	4240	2990	1320	1820	454	493	935	386	299	1397
1952	295	1290	3010	1600	2680	2700	1070	402	306	253	296	222	1177
1953	217	333	393	490	2470	2220	1350	6230	296	548	257	217	1252
1954	203	281	460	2570	2780	462	500	881	532	217	255	181	777
1955	235	222	277	310	1130	2970	4230	599	472	661	325	213	970
1956	194	306	314	378	4710	874	1170	769	330	269	176	157	804
1957	149	198	395	2030	3530	1030	1770	982	1230	369	381	693	1063
1958	339	2860	2380	839	658	1220	1340	2980	336	466	293	1210	2143
1959	307	446	407	1500	1900	1200	788	427	643	423	315	274	719
1960	353	300	1230	958	1220	2060	523	738	432	278	473	273	737
1961	456	444	510	632	2190	2410	1720	689	361	299	264	245	852
1962	231	610	1820	2210	1610	1900	971	915	454	383	297	581	999
1963	290	309	301	303	556	2046	496	1614	737	468	353	381	650
1964	220	265	367	523	580	1530	3470	786	267	352	473	338	764
1965	391	395	2260	2220	3310	2630	2290	604	398	291	293	414	1291
1966	253	298	292	405	1910	814	624	2250	277	264	490	240	676
1967	259	304	573	548	460	1300	1010	2500	470	2640	528	324	910
1968	245	303	1650	2460	962	2270	2650	1100	344	229	246	485	1079
1969	759	1230	2100	744	2230	599	3630	356	312	263	497	304	1085
Mean	314	717	1017	1932	2129	1800	1679	1080	596	468	353	381	1040

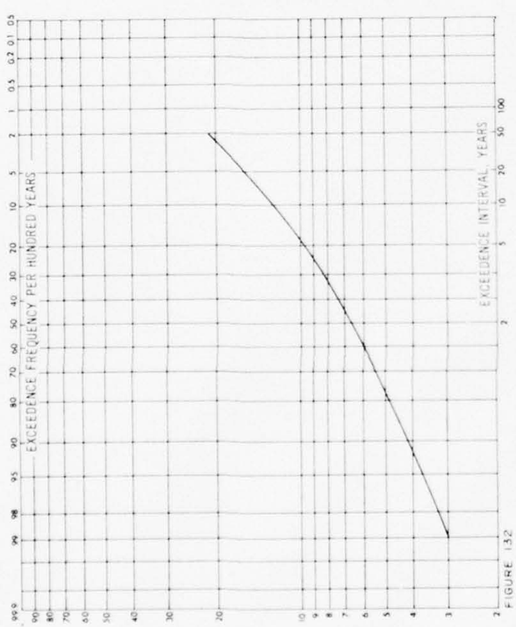


FIGURE 13.2
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
MAYFIELD CREEK - LOVELACEVILLE, KY. STA. NO. 7-0230

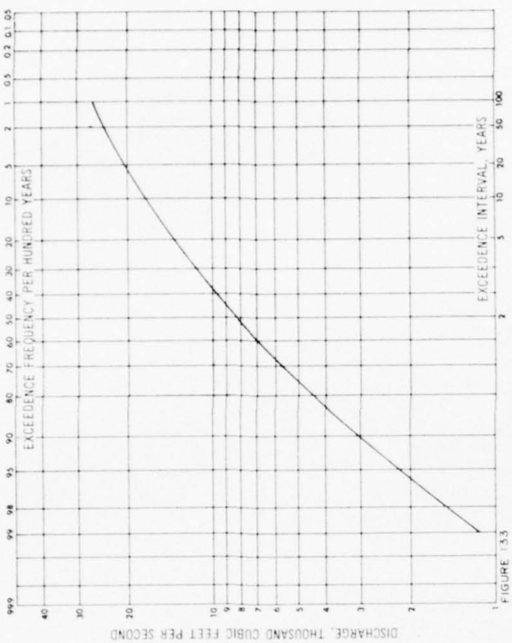


FIGURE 13.3
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
SOUTH FORK OBION RIVER - GREENFIELD, TENN. STA. NO. 7-0245

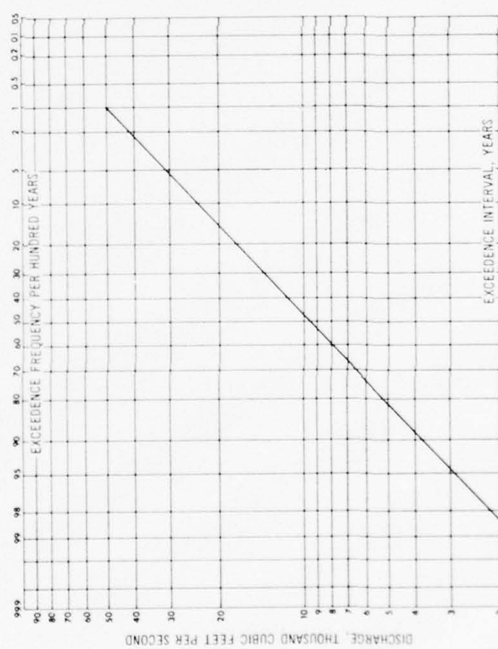


FIGURE 13.4
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
NORTH FORK OBION RIVER - UNION CITY, TENN. STA. NO. 7-0255

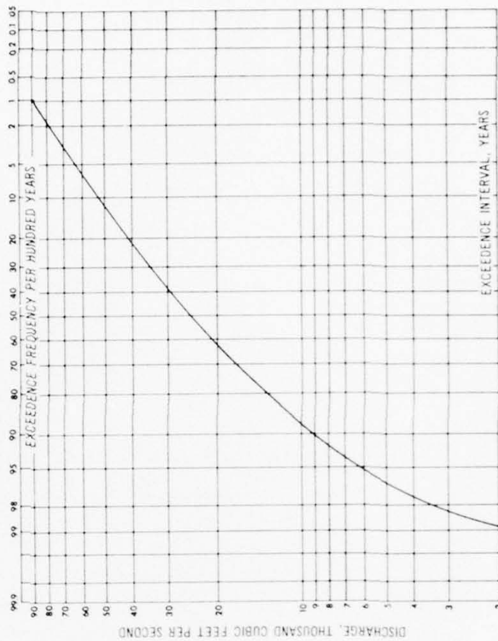


FIGURE 13.5
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
OBION RIVER, OBION, TENN. STA. NO. 7-0260

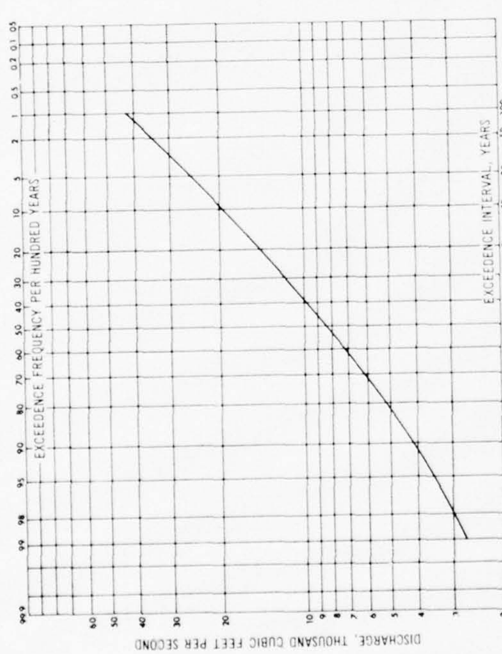


FIGURE 136
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
SOUTH FORK FORKED DEER RIVER - JACKSON, TENN. STA. NO. 7-0275

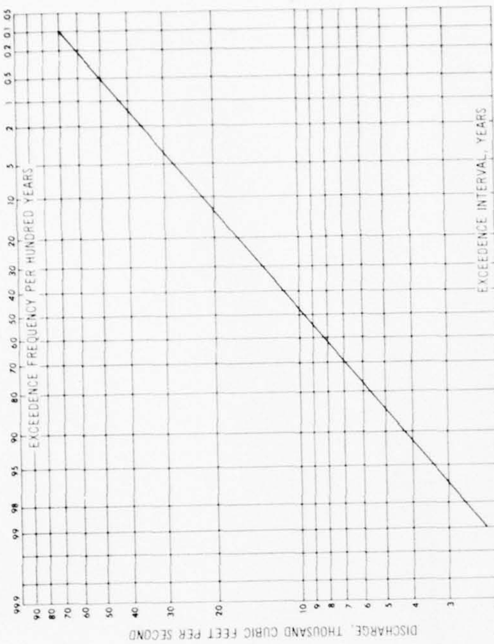


FIGURE 137
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
SOUTH FORK FORKED DEER RIVER - HALLS, TENN. STA. NO. 7-0261

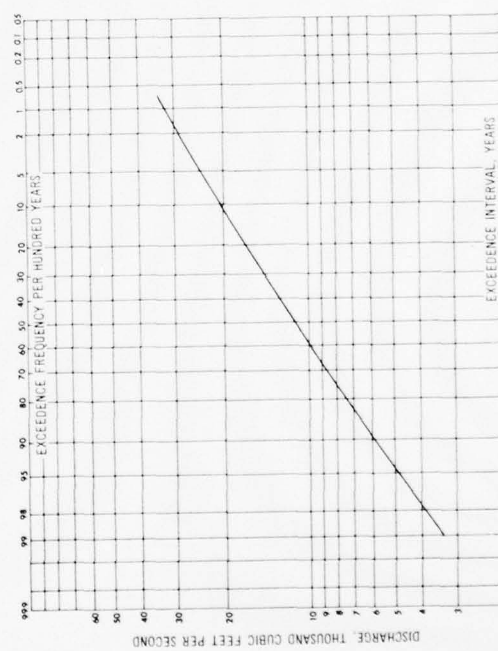


FIGURE 138
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
NORTH FORK FORKED DEER RIVER - DYERSBURG, TENN. STA. NO. 7-0291

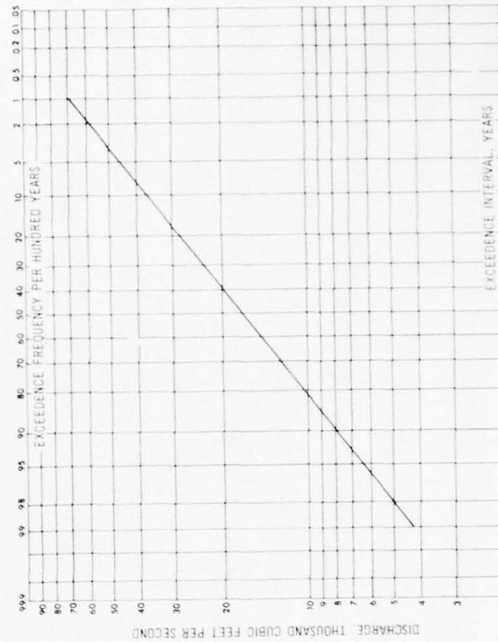


FIGURE 139
FREQUENCY CURVE OF ANNUAL PEAK FLOWS,
HATCHIE RIVER - BOLIVAR, TENN. STA. NO. 7-0[illegible]

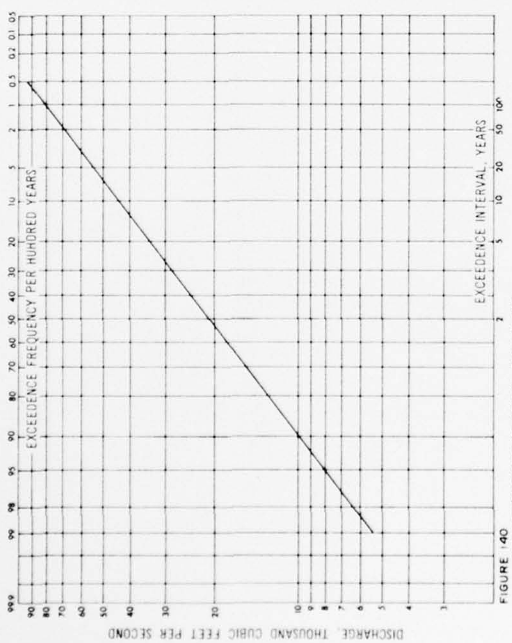


FIGURE 140
FREQUENCY CURVE OF ANNUAL PEAK FLOWS, STA. NO. 7-0300.5
HATCHIE RIVER - RIALTO, TENN.

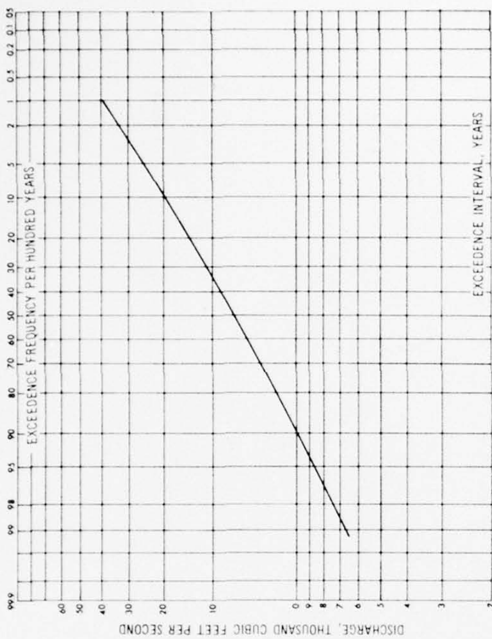


FIGURE 141
FREQUENCY CURVE OF ANNUAL PEAK FLOWS, STA. NO. 7-0302.8
LOOSAHATCHIE RIVER - BRUNSWICK, TENN.

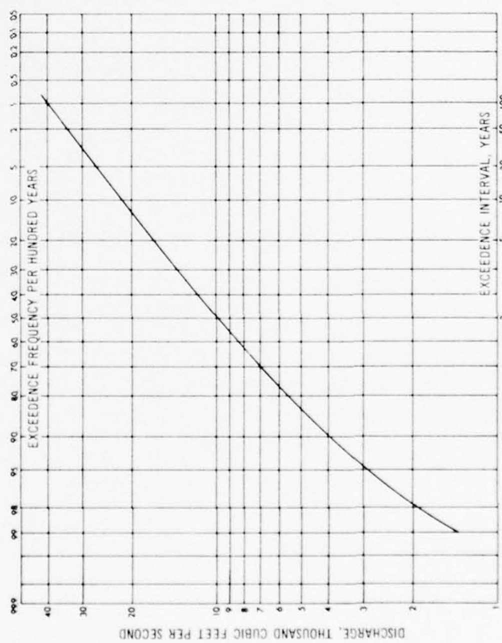


FIGURE 142
FREQUENCY CURVE OF ANNUAL PEAK FLOWS, STA. NO. 7-0305
WOLF RIVER, ROSSVILLE, TENN.

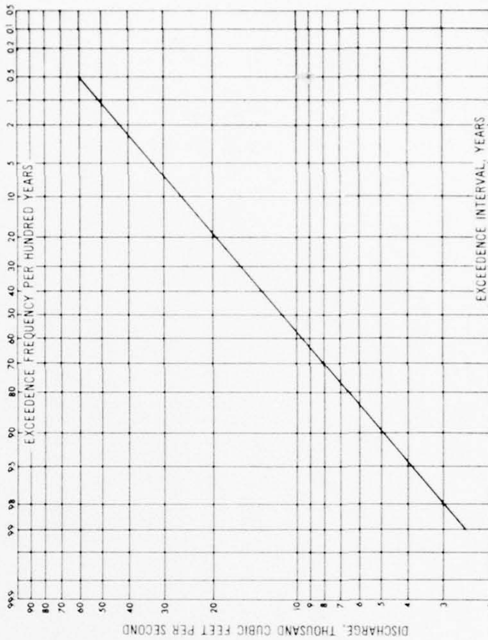


FIGURE 143
FREQUENCY CURVE OF ANNUAL PEAK FLOWS, STA. NO. 7-0317
WOLF RIVER, RALEIGH, TENN.

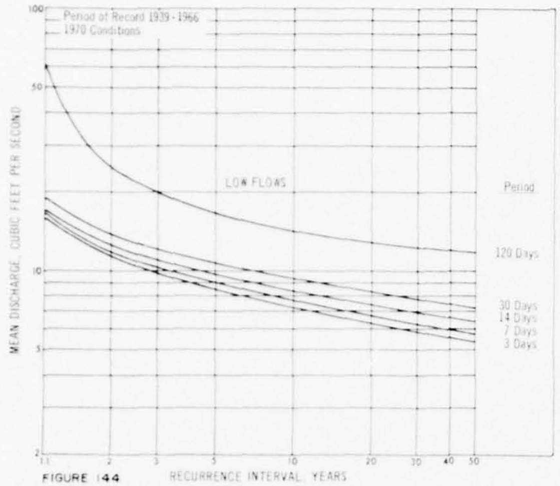


FIGURE 144

Frequency Curves, Mayfield Creek near Lovelaceville, Ky. STA. NO. 7-0230

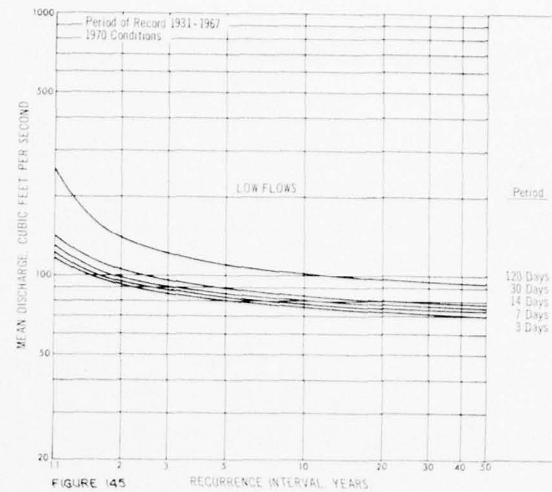


FIGURE 145

Frequency Curves, South Fork Obion River near Greenfield, Tennessee STA. NO. 7-0245

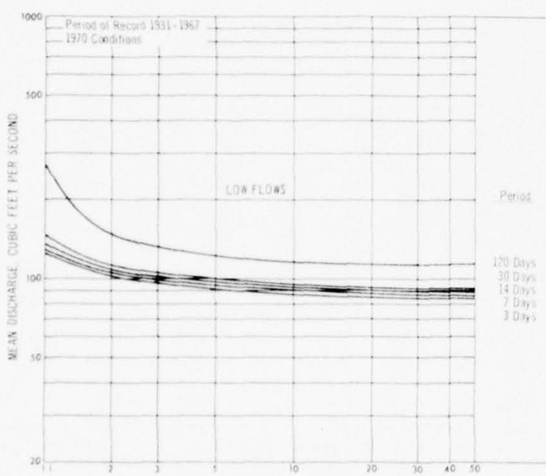


FIGURE 146

Frequency Curves, North Fork Obion River near Union City, Tennessee STA. NO. 7-0255

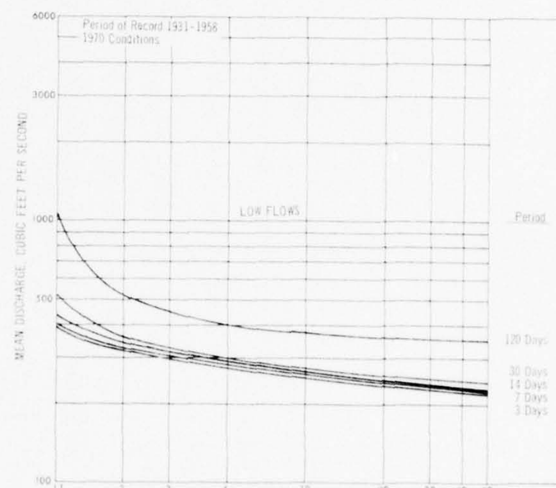


FIGURE 147

Frequency Curves, Obion River at Obion, Tennessee STA. NO. 7-0260

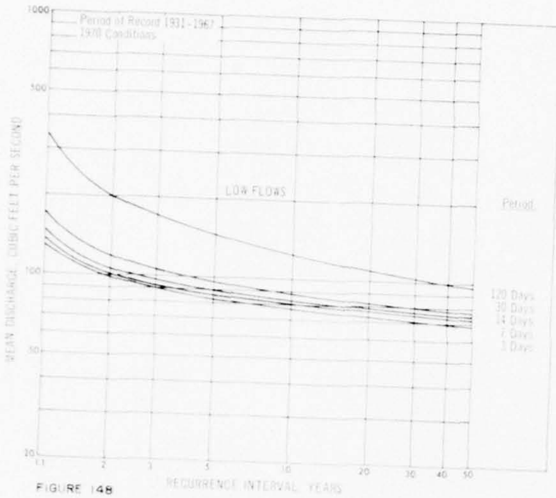


FIGURE 148

Frequency Curves, South Fork Forked Deer River at Jackson, Tennessee

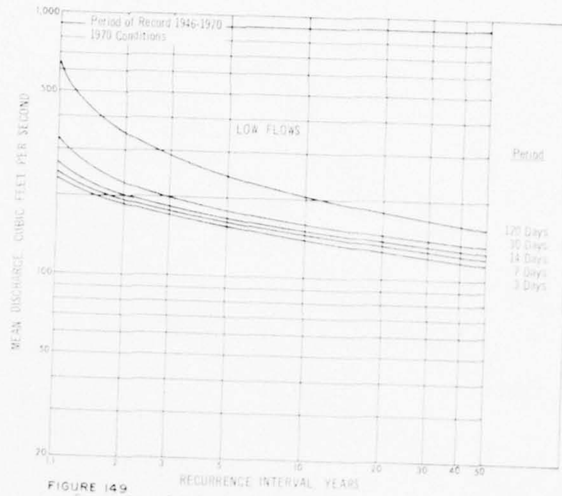


FIGURE 149

Frequency Curves, South Fork Forked Deer River near Halls, Tennessee

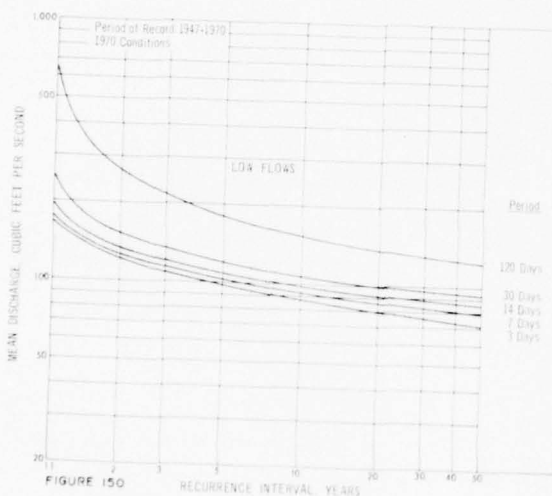


FIGURE 150

Frequency Curves, North Fork Forked Deer River at Dyersburg, Tennessee

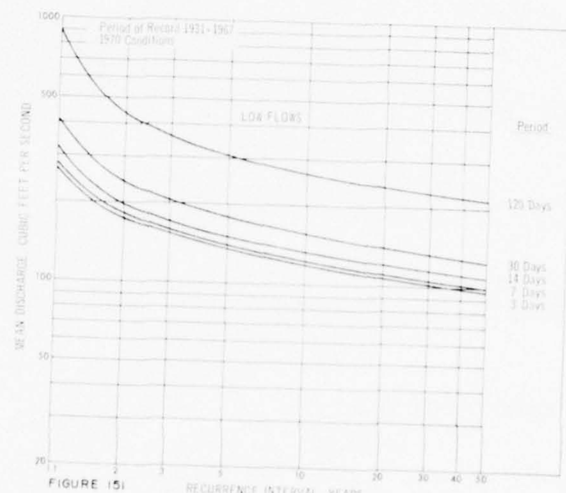


FIGURE 151

Frequency Curves, Hatchie River at Bolivar, Tennessee

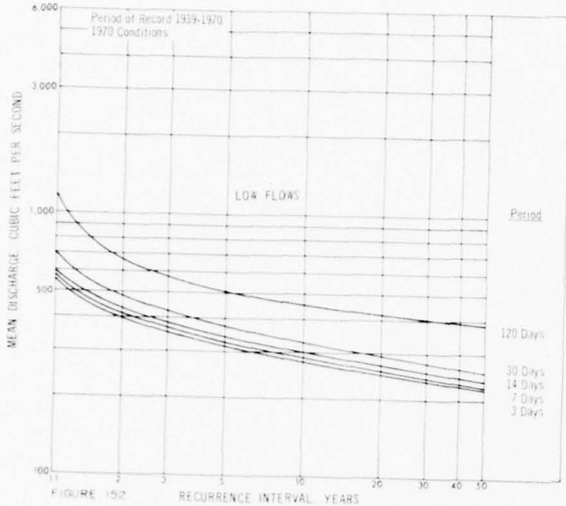


FIGURE 152

Frequency Curves, Hatchie River at Rialto, Tennessee STA. NO. 7-0300.5

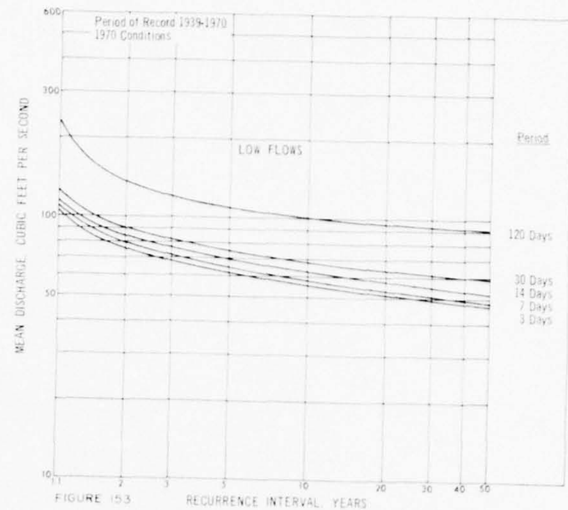


FIGURE 153

Frequency Curves, Loosahatchie River at Brunswick, Tennessee STA. NO. 7-0302.8

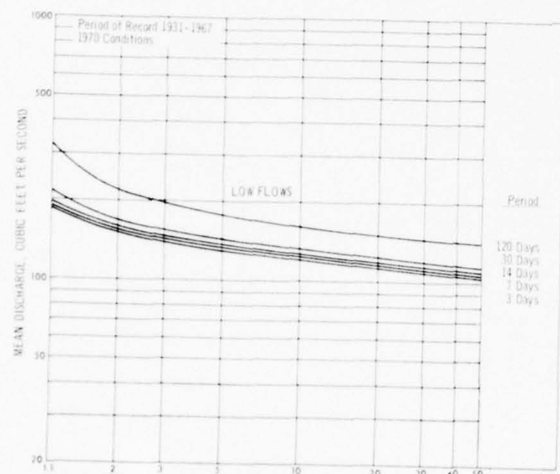


FIGURE 154

Frequency Curves, Wolf River at Rossville, Tennessee STA. NO. 7-0305

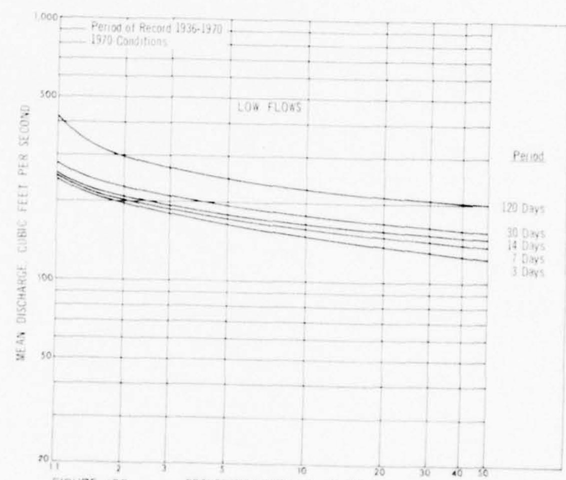


FIGURE 155

Frequency Curves, Wolf River at Raleigh, Tennessee STA. NO. 7-0317

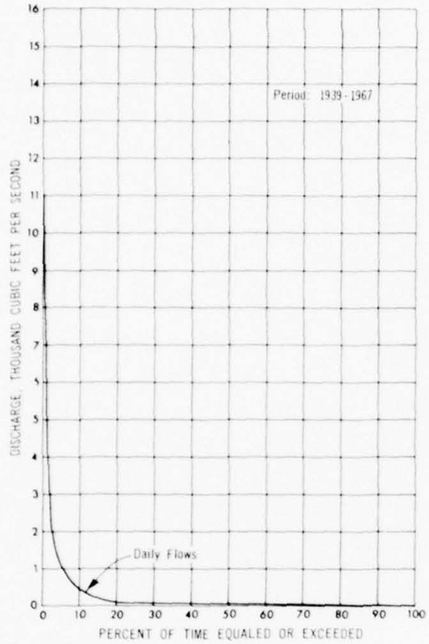


FIGURE 156

Duration Curve, Mayfield Creek near
Lovelaceville, Kentucky STA. NO. 7-0230

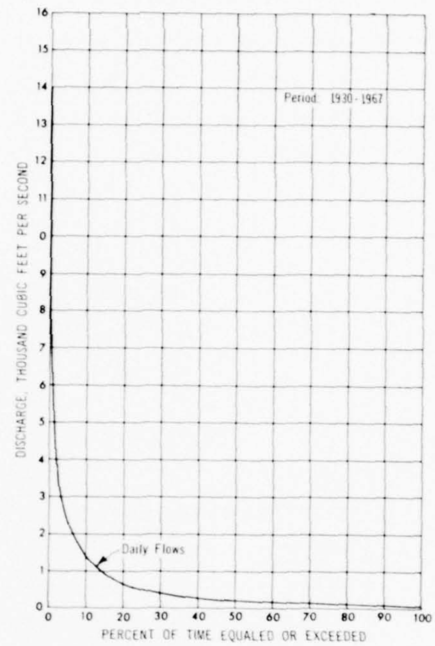


FIGURE 157

Duration Curve, South Fork, Obion River near
Greenfield, Tennessee STA. NO. 7-0245

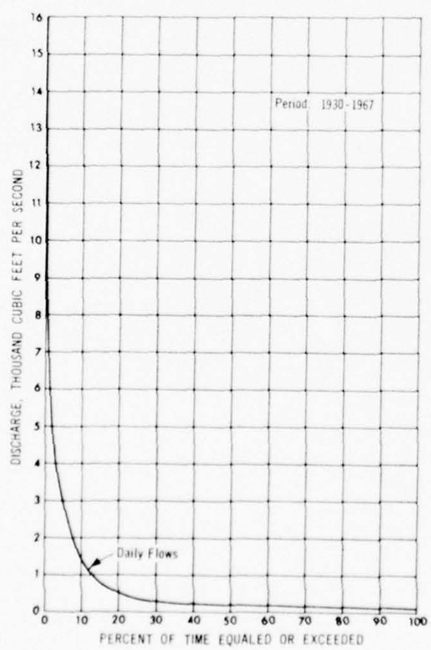


FIGURE 158

Duration Curve, North Fork, Obion River near
Union City, Tennessee STA. NO. 7-0255

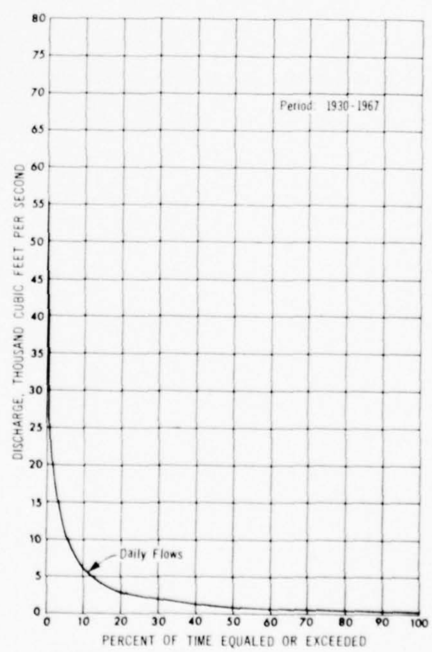


FIGURE 159

Duration Curve, Obion River at
Obion, Tennessee STA. NO. 7-0260

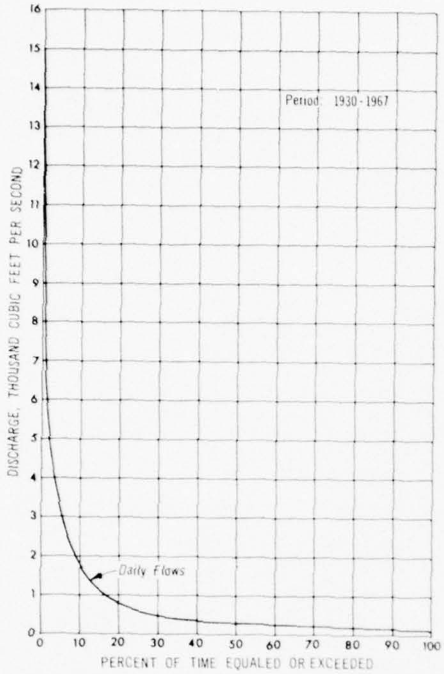


FIGURE 160

Duration Curve, South Fork, Forked Deer River at
Jackson, Tennessee STA. NO. 7-0275

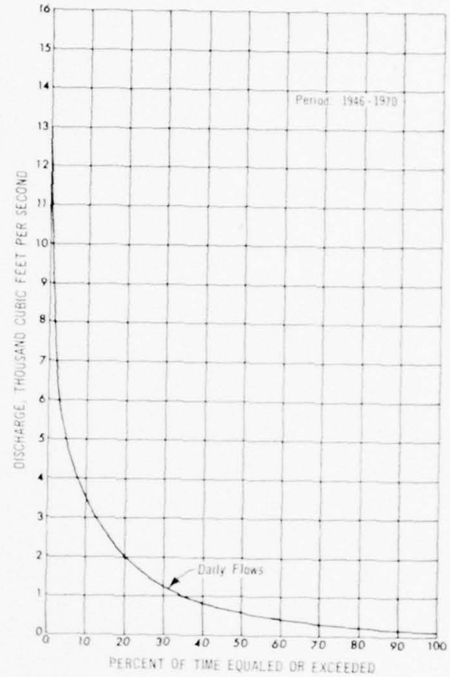


FIGURE 161

Duration Curve, South Fork Forked Deer River near
Halls, Tennessee STA. NO. 7-0281

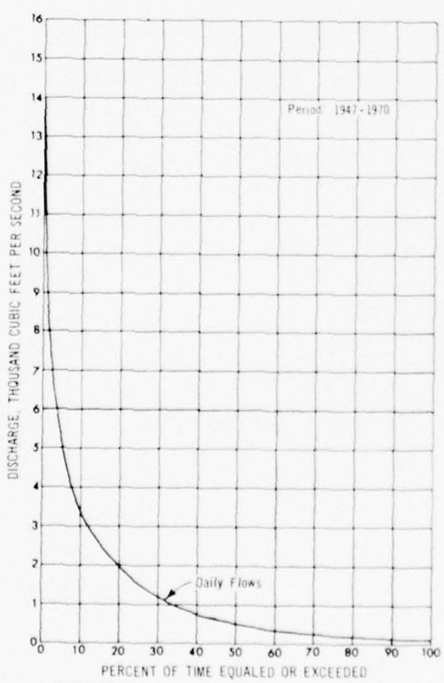


FIGURE 162

Duration Curve, North Fork, Forked Deer River near
Dyersburg, Tennessee STA. NO. 7-0291

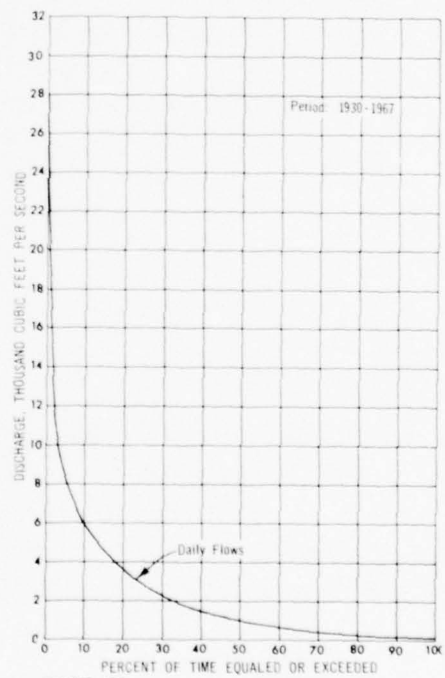


FIGURE 163

Duration Curve, Hatchie River at
Bolivar, Tennessee STA. NO. 7-0295

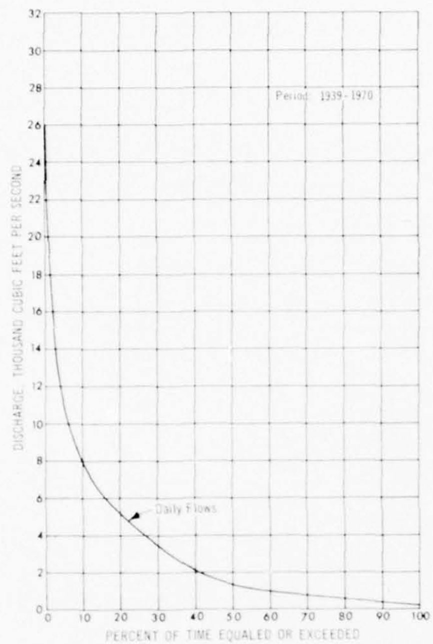


FIGURE 164

Duration Curve, Hatchie River at
Rialto, Tennessee STA. NO. 7-0300.5

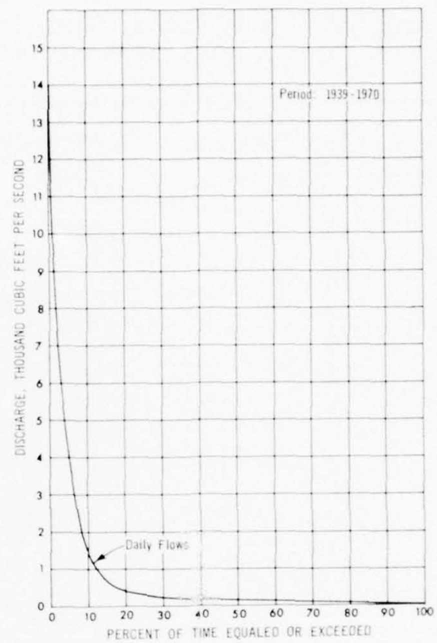


FIGURE 165

Duration Curve, Loosahatchie River at
Brunswick, Tennessee STA. NO. 7-0307.8

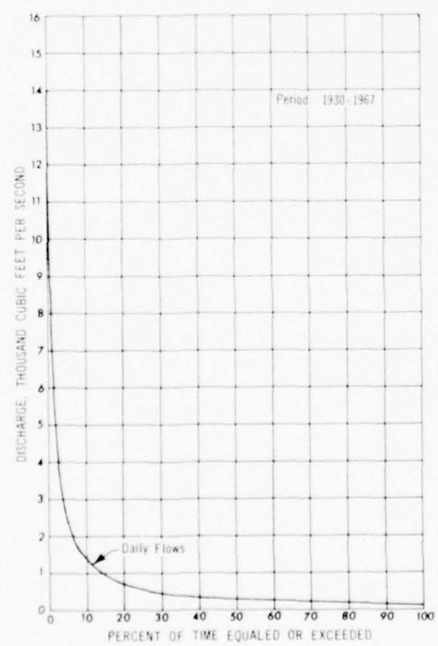


FIGURE 166

Duration Curve, Wolf River at
Rossville, Tennessee STA. NO. 7-0305

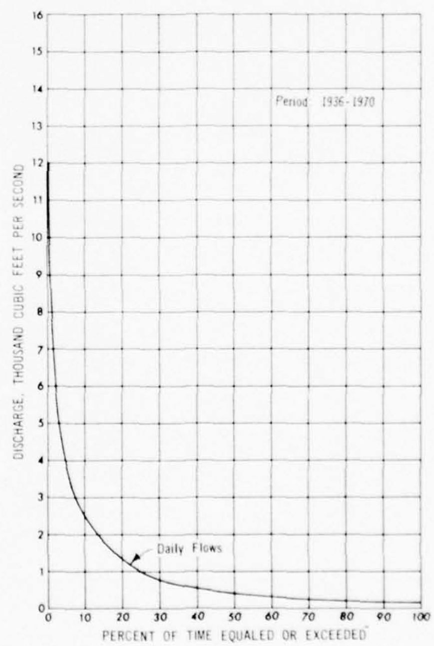


FIGURE 167

Duration Curve, Wolf River at
Raleigh, Tennessee STA. NO. 7-0317

Table 81 - Dependable Yield, Mayfield Creek at Lovelaceville, Ky., Sta 7-0230

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	31	13.3
2	1940-41	105	44.7
3	1941-43	125	53.4
4	1941-44	125	53.4
5	1940-44	135	57.9
6	1939-44	154	65.9
7	1940-46	183	78.2
8	1940-47	186	79.4
9	1940-48	187	80.0
10	1939-48	193	82.6
30	1939-68	234	100.0

Table 82 - Dependable Yield, South Fork Obion River near Greenfield, Tenn., Sta 7-0245

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	136	24.9
2	1940-41	220	40.3
3	1940-42	281	51.4
4	1940-43	316	57.8
5	1940-44	337	61.6
6	1939-44	382	69.9
7	1938-44	406	74.2
8	1936-43	434	79.4
9	1936-44	433	79.2
10	1934-43	451	82.6
40	1930-69	546	100.0

Table 83 - Dependable Yield, North Fork Obion River near Union City, Tenn., Sta 7-0255

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	174	28.5
2	1940-41	308	50.3
3	1941-43	354	57.8
4	1940-43	376	61.4
5	1940-44	390	63.8
6	1939-44	425	69.5
7	1938-44	429	70.1
8	1936-43	457	74.7
9	1936-44	456	74.6
10	1938-47	483	79.0
40	1930-69	611	100.0

Table 84 - Dependable Yield, Obion River at Obion, Tenn., Sta 7-0260

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	569	20.6
2	1940-41	1,008	36.4
3	1940-42	1,227	44.3
4	1940-43	1,308	47.3
5	1940-44	1,399	50.6
6	1939-44	1,659	60.0
7	1938-44	1,727	62.4
8	1940-47	1,796	64.9
9	1940-48	1,830	66.1
10	1939-48	1,943	70.2
40	1930-69	2,420	100.0

Table 85 - Dependable Yield, South Fork of Forked Deer River at Jackson, Tenn., Sta 7-0275

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	192	27.7
2	1940-41	296	42.6
3	1940-42	355	51.1
4	1940-43	382	55.1
5	1940-44	447	64.4
6	1959-64	516	74.3
7	1963-69	535	77.0
8	1936-43	536	77.1
9	1959-67	531	76.4
10	1959-68	542	78.0
40	1930-69	694	100.0

Table 86 - Dependable Yield, South Fork of Forked Deer River near Halls, Tenn., Sta 7-0281

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1963	631	47.4
2	1959-60	783	58.8
3	1959-61	828	62.3
4	1960-63	997	75.0
5	1959-63	967	72.7
6	1959-64	983	73.9
7	1963-69	1,073	80.6
8	1960-67	1,058	79.5
9	1959-67	1,034	77.8
10	1959-68	1,062	79.9
23	1947-69	1,330	100.0

Table 87 - Dependable Yield, North Fork of Forked Deer River at Dyersburg, Tenn., Sta 7-0291

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1963	474	35.7
2	1959-60	747	56.3
3	1959-61	853	64.3
4	1963-66	987	74.4
5	1959-63	970	73.1
6	1959-64	979	73.8
7	1963-69	1,041	78.5
8	1959-66	1,040	78.4
9	1959-67	1,045	78.7
10	1959-68	1,067	80.4
22	1948-69	1,327	100.0

Table 88 - Dependable Yield, Hatchie River, Bolivar, Tenn., Sta 7-0295

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	969	42.4
2	1940-41	1,116	48.9
3	1940-42	1,240	54.3
4	1940-43	1,276	56.0
5	1940-44	1,492	65.4
6	1938-43	1,662	72.9
7	1937-43	1,759	77.1
8	1936-43	1,729	75.8
9	1936-44	1,798	78.8
10	1934-43	1,793	78.6
40	1930-69	2,282	100.0

Table 89 - Dependable Yield, Hatchie River at Rialto, Tenn., Sta 7-0300.5

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	960	30.5
2	1940-41	1,263	40.1
3	1940-42	1,592	50.5
4	1940-43	1,680	53.3
5	1940-44	1,967	62.4
6	1940-45	2,367	75.1
7	1963-69	2,599	82.5
8	1960-67	2,697	85.6
9	1959-67	2,667	84.7
10	1959-68	2,709	86.0
30	1940-69	3,150	100.0

Table 90 - Dependable Yield, Loosahatchie River at Brunswick, Tenn., Sta 7-0302.8

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	141	19.8
2	1940-41	192	27.0
3	1940-42	295	41.5
4	1940-43	337	47.4
5	1940-44	428	60.2
6	1963-68	533	75.1
7	1963-69	533	75.1
8	1960-67	552	77.7
9	1959-67	544	76.6
10	1959-68	553	77.9
30	1940-69	710	100.0

Table 91 - Dependable Yield, Wolf River at Rossville, Tenn., Sta 7-0305

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	277	42.2
2	1940-41	291	44.3
3	1940-42	357	54.3
4	1940-43	387	58.9
5	1940-44	449	68.4
6	1938-43	504	76.8
7	1936-42	517	78.8
8	1936-43	512	78.0
9	1936-44	533	81.1
10	1934-43	543	82.7
40	1930-69	656	100.0

Table 92 - Dependable Yield, Wolf River at Raleigh, Tenn., Sta 7-0317

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (c.f.s.)	Percent of Mean for Period of Record
1	1941	395	38.0
2	1940-41	414	39.8
3	1940-42	564	54.2
4	1940-43	611	58.8
5	1940-44	698	67.1
6	1959-64	787	75.7
7	1938-44	838	80.6
8	1959-66	836	80.4
9	1959-67	844	81.2
10	1959-68	868	83.4
33	1937-69	1,040	100.0

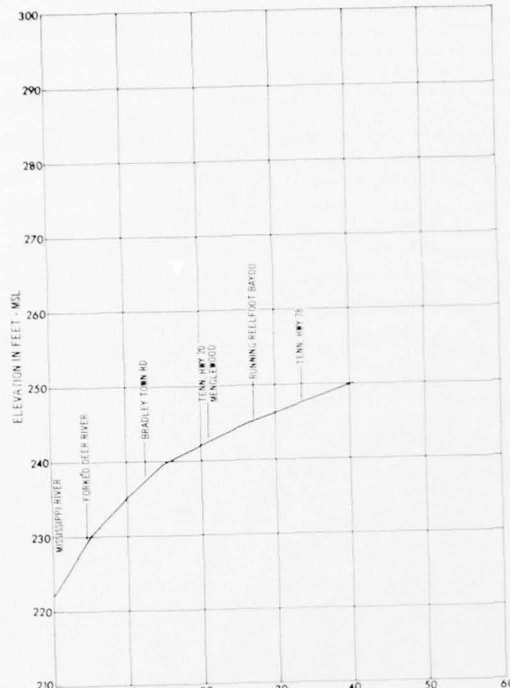


FIGURE 168 PROFILE OBION RIVER

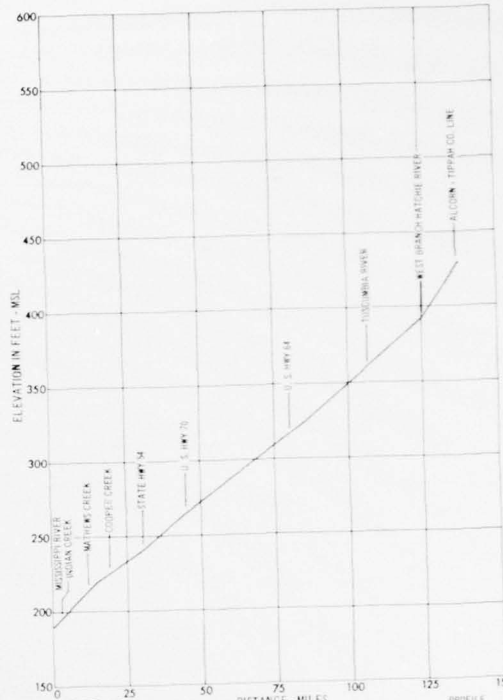


FIGURE 169 PROFILE HATCHIE RIVER

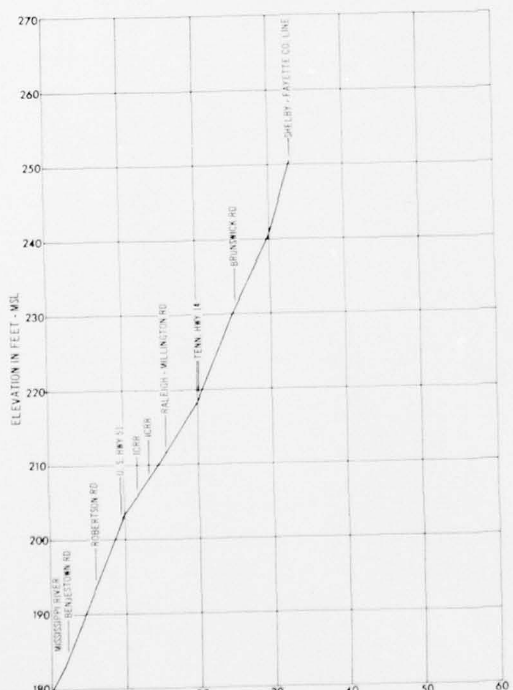


FIGURE 170 PROFILE LOOSAHATCHIE RIVER

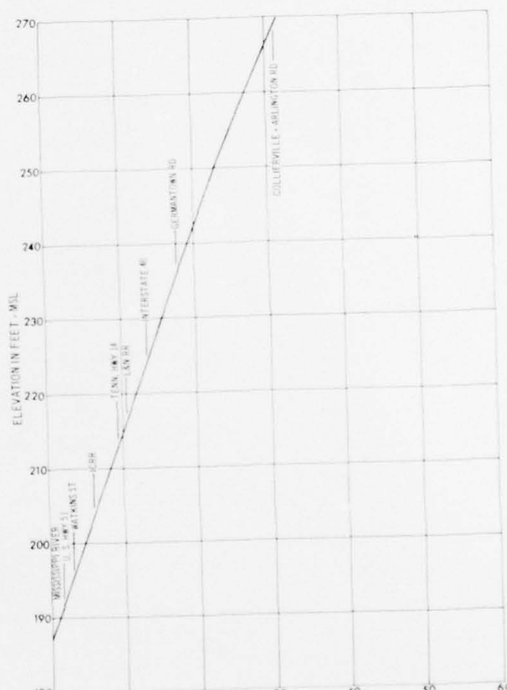


FIGURE 171 PROFILE WOLF RIVER

Table 93 - Chemical Analyses of Low-Flow Surface Waters in WRPA 3 in the Lower Mississippi Region, Milligrams Per Liter

Geologic units in drainage basin above sampling station	Date sampled	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
	07024200 Crooked Creek near Huntingdon, Tenn. (drainage area, 26.5 sq mi)																		
	10-18-60	9	8.5	0.13	2.2	1.0	2.7	0.5	12	4.4	1.2	0.1	0.8	27	10	0	31	6.5	12
	10-10-62	10	8.5	.00	2.1	.9	2.6	.4	14	2.4	1.0	.1	.7	26	8	0	32	7.2	2
	07024300 Beaver Creek near Huntingdon, Tenn. (drainage area, 55.5 sq mi)																		
McNairy Sand Member of Ripley Formation	10-18-60	23	8.2	0.26	4.3	0.1	2.5	0.5	13	5.8	1.2	0.1	0.8	30	11	0	39	6.3	20
	10-10-62	26	8.7	.02	2.7	1.2	2.9	.6	16	5.2	1.0	.0	.7	39	12	0	37	7.1	1
	07027300 South Fork Forked Deer River near Henderson, Tenn. (drainage area, 161 sq mi)																		
	8-10-61	58	3.5	0.04	2.5	0.5	1.9	1.1	12	3.0	1.5	0.0	0.1	20	8	0	30	6.7	5
	10- 8-62	59	8.1	.00	1.9	1.1	2.1	1.0	14	1.6	1.2	.0	.2	24	9	0	29	6.5	1
	07027400 Middle Fork Creek near Luray, Tenn. (drainage area, 21.5 sq mi)																		
	8-10-61	11	2.9	0.05	1.3	0.6	1.8	0.4	9	0.0	1.5	0.0	0.1	13	6	0	21	6.4	5
	10- 8-62	13	8.2	.00	1.9	.8	1.8	.9	13	.8	.8	.0	.3	21	8	0	24	6.6	2
	07029370 Cypress Creek at Selmer, Tenn. (drainage area, 44 sq mi, approx.)																		
	10-19-60	17	8.6	0.30	2.1	0.6	1.7	0.6	12	0.2	1.2	0.1	1.1	20	8	0	26	6.4	26
	10- 8-62	21	8.0	.00	2.4	.7	1.7	.8	13	2.2	.6	.0	.2	23	9	0	27	6.6	3
	07027600 Johnson Creek near Jackson, Tenn. (drainage area, 34 sq mi, approx.)																		
	10-19-60	0.91	8.9	0.06	2.9	1.0	3.3	0.8	21	0.2	1.0	0.1	0.9	29	11	0	40	6.4	3
	8-10-61	.77	7.8	.04	1.4	1.5	3.5	.8	18	.8	2.0	.0	.2	27	10	0	38	6.6	4
Claiborne Group undifferentiated--continued	10- 8-62	2.2	6.7	.02	3.2	1.9	2.8	2.3	25	2.4	1.4	.1	1.4	34	16	0	46	7.1	2
	07029440 Porters Creek near Middleton, Tenn. (drainage area, 40.4 sq mi)																		
	10-19-60	11	7.4	0.18	2.6	1.6	2.1	1.0	16	2.4	1.8	0.1	0.5	28	13	0	37	6.6	25
	10- 9-62	7.2	8.0	.00	2.2	.9	1.7	1.2	14	1.6	1.2	.0	.2	24	9	0	27	6.6	4
	07030200 Loosahatchie River near Laconia, Tenn. (drainage area, 26.2 sq mi)																		
	10-19-60	1.6	7.9	0.07	1.9	0.6	2.9	0.8	16	0.0	1.5	0.1	0.7	24	7	0	30	6.5	12
	10- 9-62	.46	11	.00	2.6	1.0	3.8	1.0	22	1.0	1.2	.0	.3	33	10	0	38	6.9	2

Table 93 - Chemical Analyses of Low-Flow Surface Waters in WRPA 3 in the Lower Mississippi Region, Milligrams Per Liter--Continued

Geologic units in drainage basin above sampling station	Date sampled	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
						07030500 Wolf River at Rossville, Tenn. (drainage area, 503 sq mi)													
Claiborne Group undifferentiated--continued	8-16-61	177	6.8	0.04	1.6	1.0	2.5	0.5	15	0.6	1.5	0.0	0.2	22	8	0	30	6.6	5
	10- 9-62	241	8.5	.00	2.4	1.0	2.6	1.3	19	2.0	.8	.0	.1	28	10	0	33	6.6	2
						07023500 Obion Creek at Pryorsburg, Ky. (drainage area, 36.8 sq mi)													
Eocene deposits undifferentiated	11-22-60	0.03	7.0	0.00	7.7	4.3	3.0	3.1	44	5.4	2.5	0.3	0.5	56	36	0	94	6.7	25
	8-24-62	.01	2.9	.24	3.6	2.0	1.1	6.7	22	6.8	1.8	.2	1.5	38	17	0	59	6.8	50
						07024050 Cane Creek near Clinton, Ky. (drainage area, 16.9 sq mi)													
	11-23-60	0.39	5.0	0.24	5.8	2.5	6.7	5.2	22	20	5.2	0.3	1.0	63	25	7	100	6.4	70
	8-24-62	.03	6.4	.00	11	5.0	9.3	3.4	80	2.0	3.0	.4	1.8	81	48	0	130	8.1	3
						07029410 Mosses Creek near Pocahontas, Tenn. (drainage area, 47.6 sq mi)													
McNairy Sand Member of Ripley Formation--Continued	10-19-60	21.9	7.5	0.33	1.8	1.3	1.8	0.8	12	2.4	2.0	0.1	0.8	25	10	0	30	6.4	37
		19.3	7.8	.00	2.1	.8	1.6	.8	13	2.0	1.2	.0	.2	23	8	0	26	6.6	4
						07024250 Quins Creek near Huntingdon, Tenn. (drainage area, 43.5 sq mi)													
Wilcox Group undifferentiated	10-18-60	6.9	7.4	0.44	2.9	0.8	2.0	0.8	16	0.0	1.5	0.1	1.2	25	10	0	33	6.5	40
	10-10-62	11.2	8.8	.00	2.7	1.1	2.1	1.1	15	2.0	.8	.0	.4	28	11	0	33	6.7	3
						07024400 Reedy Creek near Trezevant, Tenn. (drainage area, 57 sq mi, approx.)													
Wilcox and Claiborne Groups undifferentiated	10-18-60	5.6	9.1	0.09	2.5	0.8	3.2	0.7	17	0.0	2.2	0.1	1.8	29	10	0	37	6.5	15
	10- 9-62	7.3	9.4	.00	2.7	1.2	3.0	1.1	19	2.0	1.0	.0	.4	30	12	0	37	6.5	1
						07025350 Cypress Creek near Lathem, Tenn. (drainage area, 36.7 sq mi)													
Claiborne Group undifferentiated	10-18-60	0.61	8.6	0.07	3.0	0.8	4.0	0.8	21	0.2	2.0	0.1	0.6	30	11	0	43	6.7	15
	10- 8-62	.70	9.0	.00	2.2	1.2	4.1	.9	22	1.2	1.6	.1	.7	32	10	0	43	7.1	1
						07027700 Mud Creek near Bells, Tenn. (drainage area, 27 sq mi, approx.)													
	10-20-60	0.42	8.9	0.10	2.5	0.8	4.2	0.9	20	0.0	2.5	0.1	0.6	30	10	0	42	6.2	23
	10-10-62	.56	11	.00	2.5	.8	4.4	.8	22	1.4	1.0	.0	.2	33	9	0	38	7.1	1

Table 93 - Chemical Analyses of Low-Flow Surface Waters in WRPA 3 in the Lower Mississippi Region, Milligrams Per Liter--Continued

Geologic units in drainage basin above sampling station	Date sampled	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
	07023100 West Fork Mayfield Creek near Bardwell, Ky. (drainage area, 50.9 sq mi)																		
Eocene deposits undifferentiated and Pliocene(?) deposits--Continued	11-22-60	1.84	7.3	0.23	3.8	2.3	5.3	1.0	31	4.4	3.2	0.2	0.3	42	19	0	65	6.2	50
	07026030 Richland Creek near Obion, Tenn. (drainage area, 17.7 sq mi)																		
Terrace deposits and loess	10-20-60	1.04	5.6	0.01	52	26	6.5	2.5	296	4.6	3.0	0.3	1.2	248	236	0	425	7.4	7
	11- 8-62	1.44	4.3	.02	40	23	6.8	2.4	a273	4.6	2.0	.3	1.0	234	215	0	366	8.5	2

a Includes equivalent of 10 mg/l of carbonate (CO_3)

GROUND WATER

Cretaceous rocks crop out in the southeastern part of WRPA 3 and are overlain to the west by progressively younger Tertiary and Quaternary deposits. The oldest unit exposed at the surface is the Coffee Sand. The younger units outcropping to the west are the Demopolis Formation, McNairy Sand, Owl Creek Formation, Midway Group, Wilcox Group (or Wilcox Formation), Claiborne Group, and Jackson Formation. Much of the upland surface is blanketed by terrace deposits and loess. The narrow, irregular floodplain east of the Mississippi River is underlain by Quaternary alluvium.

The major aquifers in WRPA 3 are the McNairy Sand, lower Wilcox aquifer, and the Memphis Sand. Other aquifers underlying parts of the area are in Paleozoic rocks, the Coffee Sand, Cockfield Formation, and Mississippi River Valley alluvial aquifer (figure 172).

Paleozoic Aquifers

Paleozoic rocks underlying the eastern part of the area may be a potential source of ground water. The only large withdrawal of ground water from the Paleozoic rocks is in Alcorn County, Miss., where the municipal and industrial water supply, about 3 mgd, is obtained from Paleozoic chert in the Corinth area.

Results of aquifer tests at Corinth show coefficients of transmissibility ranging from 15,000 to 60,000 gpd per foot. Wells in the Paleozoic at Corinth average about 450 feet in depth, and yields are reported to be as high as 800 gpm [72].

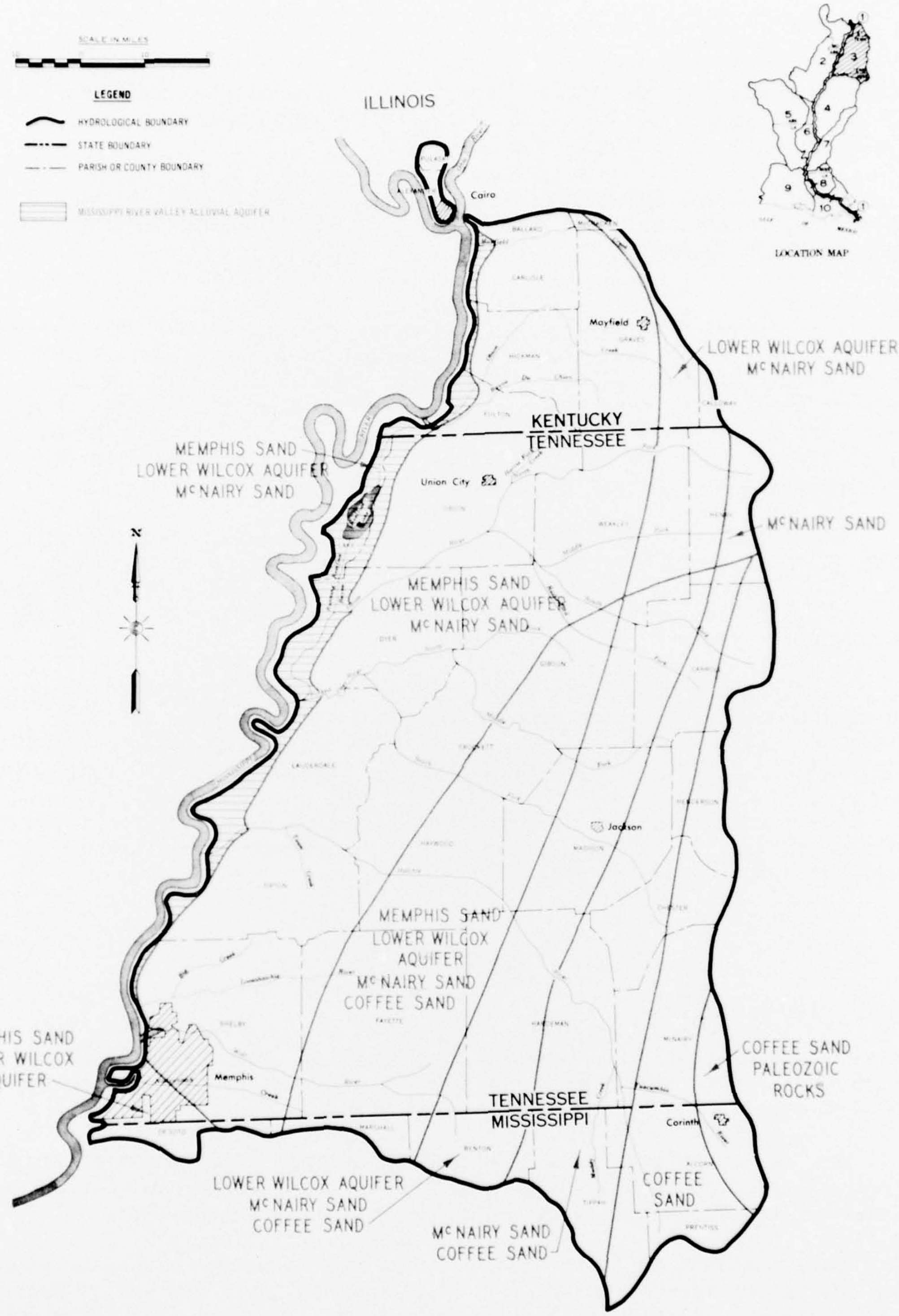
Water from the Paleozoic aquifer is moderately hard. The dissolved-solids content, about 300 mg/1, is mostly bicarbonate, chloride, and sodium. The temperature is about 65° F.

Cretaceous Aquifers

Coffee Sand

The Coffee Sand is the best source of ground water in several counties in Tennessee and in Tippah County, Miss. In part of the area, the Coffee Sand is underlain by the Eutaw Formation; however, the Eutaw is too thin to yield significant quantities of water. The Coffee is not used in much of the area where it contains fresh water because the McNairy Sand is present at shallower depths.

The Coffee Sand may have permeabilities as high as 300 gpd per square foot, and the coefficient of transmissibility may be as high as



LOWER MISSISSIPPI REGION
COMPREHENSIVE STUDY

GEOLOGIC SOURCES OF GROUND WATER

WRPA 3

FIGURE 172

30,000 gpd per foot in Alcorn County, Miss. The largest reported yield for a well in the aquifer is about 600 gpd; however, the usual yield for wells is 250 gpm or less.

Municipal and industrial pumpage from the Coffee Sand in WRPA 3 is about 2 mgd. The estimated potential yield of the Coffee Sand in the area is about 10 mgd.

McNairy Sand

The McNairy Sand is the most extensive aquifer in WRPA 3. The formation crops out in the extreme eastern part of the area and contains fresh water except in part of the Memphis area (figure 60). Most of the present withdrawals from the aquifer are in or near the outcrop, and few wells are more than a few hundred feet in depth. The maximum known depth for wells in the aquifer ranges from several hundred feet in western Kentucky to about 2,300 feet in the Memphis area.

Results of aquifer tests in Kentucky and Tennessee indicate an average coefficient of transmissibility of about 28,000 gpd per foot. Based on these results, large wells in the McNairy Sand may be expected to yield 1 mgd or more with less than 100 feet of drawdown at favorable locations in Kentucky and Tennessee.

Water from the McNairy Sand in areas where it is now used is low in dissolved solids and it is generally a calcium bicarbonate type. The dissolved-solids content of the water increases to the southwest and the water is slightly saline in extreme southwestern Shelby County, Tenn.

Water withdrawn from the McNairy Sand for all uses is estimated to be about 25 mgd in WRPA 3. The aquifer is estimated to be capable of yielding about 60 mgd in WRPA 3.

Tertiary Aquifers

Lower Wilcox Aquifer

The lower Wilcox aquifer is exposed at the surface in WRPA 3 as a narrow irregular belt in Carroll, Chester, Hardeman, and Madison Counties, Tenn. (figure 55). The aquifer contains fresh water throughout the area.

Results of pumping tests indicate an average coefficient of transmissibility of about 95,000 gpd per foot in WRPA 3. The coefficient of permeability ranges upward from about 500 gpd per square foot.

Large wells made in the lower Wilcox are commonly capable of yielding 500 gpm or more. The largest yield reported is 2,000 gpm at West Memphis, Ark., and one well at Memphis yields 1,600 gpm [19]. Yields of 600 gpm are obtained at places in western Kentucky [27].

Water in the lower Wilcox is generally a soft sodium bicarbonate type. The most troublesome chemical constituent is iron, which commonly occurs in concentrations of more than 0.3 mg/l. The dissolved-solids content of the water does not exceed 500 mg/l in WRPA 3.

Ground water withdrawals from the lower Wilcox aquifer are about 25 mgd in Tennessee and Kentucky. Presently, most withdrawals from the lower Wilcox aquifer are made at Memphis, Tenn., and in and adjacent to the outcrop area. The lower Wilcox is capable of yielding about 40 mgd in WRPA 3.

Memphis Sand

Most of the ground water now being produced in WRPA 3 is withdrawn from the Memphis Sand [32] (the Memphis Sand is equivalent to the Memphis aquifer in Arkansas, Kentucky, and Missouri). Due to its thickness, areal extent, excellent quality water, and excellent hydraulic characteristics, the Memphis Sand also has the largest potential in the area for meeting future requirements for ground water.

Aquifer test results indicate coefficients of transmissibility ranging from 20,000 to 410,000 gpd per foot. Sixty tests in the Memphis area showed an average transmissibility of 250,000 gpd per foot [19]. Assuming average hydraulic conditions, wells yielding more than 1,500 gpm might be constructed at any location underlain by the Memphis Sand.

Water from the Memphis Sand commonly contains less than 150 mg/l of dissolved solids; however, the water is generally slightly acidic and commonly contains excessive iron in solution.

The present pumpage from the Memphis Sand in WRPA 3 is about 200 mgd, of which about 180 mgd is withdrawn in the Memphis area. According to Moore [64], if the hydraulic gradient in the Memphis Sand were increased to the average dip of the aquifer, the aquifer would transmit about 650 mgd downdip from the outcrop area. Under these conditions, the total pumping lift in the Memphis area will average about 500 feet.

Quaternary Aquifers

Mississippi River Valley Alluvial Aquifer

The Mississippi Alluvial Plain ends abruptly at the foot of the bluffs on the east side of the valley. In places, the river impinges on the bluffs (as at Memphis) and in other places the alluvial deposits may extend more than 10 miles east of the river.

The hydraulic characteristics of the Mississippi River Valley alluvial aquifer vary considerably, but the coefficient of transmissibility in WRPA 3 probably is in the 100,000 to 200,000 gpd per foot range.

Due to the excellent hydraulic characteristics of the alluvium and to seasonal replenishment by precipitation, the Mississippi River Valley alluvial aquifer is a major source of ground water. The potential of the aquifer is even larger where wells are installed near the Mississippi River or other large streams where pumping might induce recharge to the aquifer from the streams.

Water from the alluvial aquifers, generally a hard calcium bicarbonate type, is more highly mineralized than water from the Memphis Sand and the lower Wilcox aquifer in WRPA 3. Although the iron content of the water varies from place to place, the alluvial water generally requires treatment for iron removal and softening when used as a municipal or industrial supply.

The potential yield of the Mississippi River Valley alluvial aquifer is large, particularly if well fields are located near the Mississippi River. Wells designed for irrigation or industrial use may be expected to yield 2,000 gpm or more.

Effects of Ground Water Withdrawals and Management Considerations

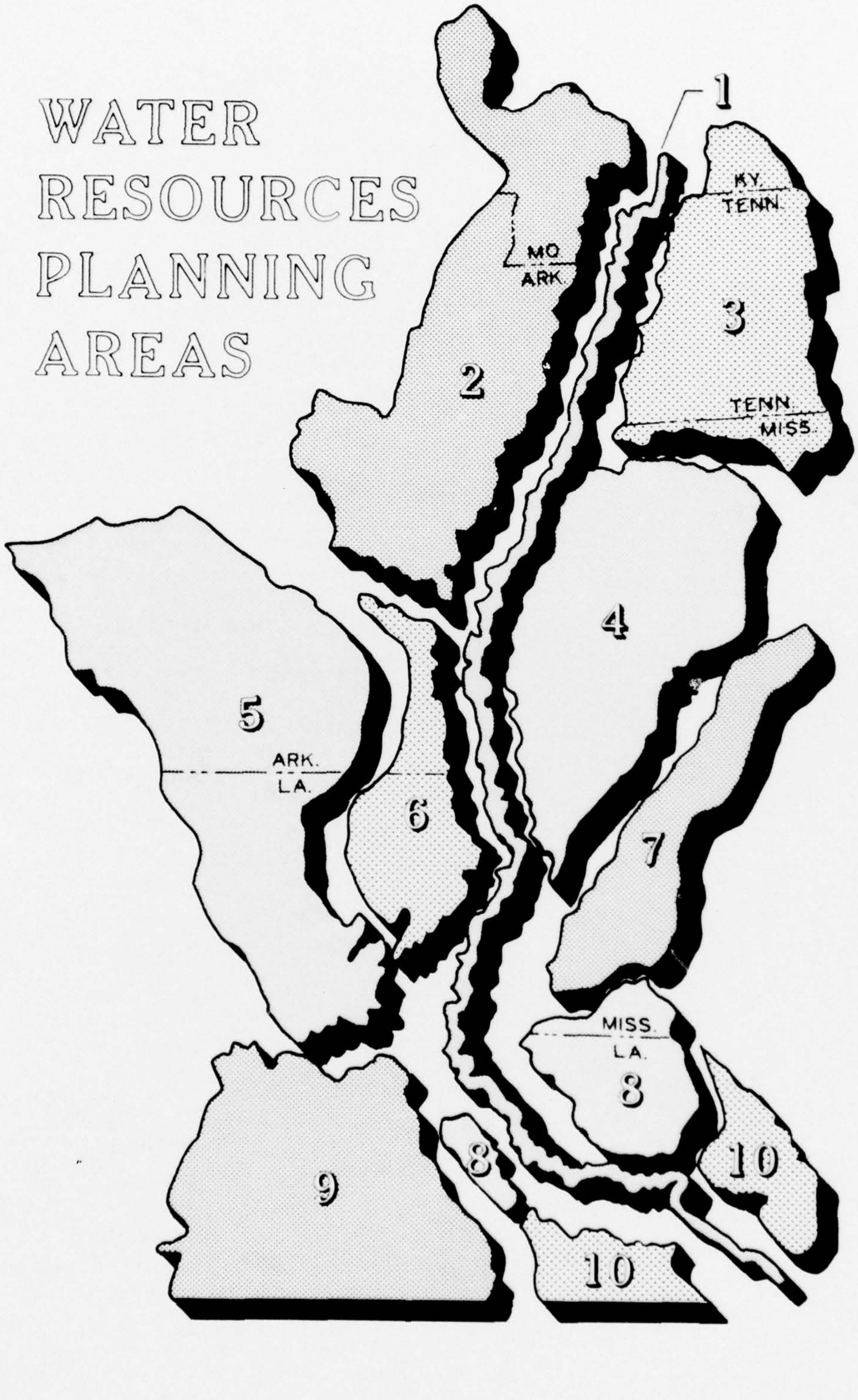
Ground water withdrawals in the Memphis area have resulted in a moderately large cone of depression in the potentiometric surface of the Memphis Sand [87]. Pumpage from the lower Wilcox aquifer has resulted in a cone of depression similar to but smaller than the cone of depression in the Memphis Sand. Withdrawals from the Mississippi River Valley alluvial aquifer are replaced through recharge from precipitation during the winter and spring, and permanent water level declines have not occurred.

Water level declines in the lower Wilcox aquifer and the Memphis Sand have been small in WRPA 3 outside the area affected by withdrawals at Memphis. Water level declines in the McNairy and Coffee Sand have been negligible in most of the area.

The largest potential for ground water development in WRPA 3 is in a zone several miles wide paralleling the Mississippi River. Most of the ground water being produced in the area is withdrawn at Memphis. More detailed studies are needed to determine the optimum yield of the Memphis Sand and lower Wilcox aquifer in the Memphis area and to determine the effect of the withdrawals on the aquifers in the remainder of WRPA 3 and adjoining parts of WRPA's 2 and 4. The McNairy Sand, a major aquifer in much of the area, is used as a source of ground water only in a small part of the area where it contains fresh water. Estimates of the potential of the McNairy Sand as an aquifer are based on extremely sparse data. A comprehensive study of this aquifer is needed.

The lowering of water levels in the Memphis aquifer will induce recharge from other sources, the most significant being the Mississippi River Valley alluvial aquifer. Investigations to determine the significance of the changes, particularly in water quality, are needed.

Although the Mississippi River Valley alluvial aquifer is available only in a small part of WRPA 3, the potential of the aquifer is enormous, particularly in areas adjacent to the Mississippi River where recharge might be induced from the stream.



WATER RESOURCES PLANNING AREAS
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